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ORIGINAL ARTICLES

THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF COTTON IN SOUTH GUJERAT (SURAT)

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(Received for publication on 3 February 1951)

(With four text-figures)

SURTI cotton (*G. Herbaceum* Var. *acerifolium* [Guill ; Perr.] was grown in the area bounded by river Narmada on the north and the river Ambika in the south of Surat District. On pre-war basis the total area under cotton was about 600,000 acres which formed 25 to 40 per cent of the total cultivated area.

The cotton soils of South Gujerat were black and clayey, four to six feet in depth. Their chief characteristic was that they expanded on wetting and contracted and cracked on drying from the month of October onward. The physical texture consisted mainly of fine sand, silt of different fineness and clay, and it was fairly uniform at different depths. Joshi [1941] has found that these soils were fairly good in organic matter, lime and in phosphoric acid. Average total nitrogen to a depth of 90 cm. varied from 0·035 to 0·045 per cent of which 95 per cent was organic nitrogen and the rest was present in inorganic form.

Rainfall in this tract varied from 30 inches in the north to 50 inches in the south and was mostly received in the months of June and October. The main rainfall of the season was received in the months of July and August.

The cotton crop in this tract was sown towards the end of June and for two months after sowing both the minimum and maximum temperatures did not vary to a marked extent. During these rainy months the crop made very little growth. Thereafter the maximum temperature steadily went up and highest mean maximum temperature of the cotton season was reached in the month of October after which it declined rapidly. The growth of the crop was most rapid during this period. Then the temperatures began to fall till January and the reproductive growth occurred during the interval. The temperatures again began to rise during the period of the maturation of the crop until the crop was picked in March to April. Rarely once in several years frost occurred which has been known to cause extensive damage to the crop.

The humidity was very high during rainy months and it fell in September to November after which it remained constant up till the end of the picking period.

The records of rainfall, temperatures and relative humidity during the cotton season in the years of investigations were kept. These data for the year 1944-45 are only given in Table I.

TABLE I

Meteorological data for 1944-45 at the Agricultural Farm, Surat

	June	July	August	September	October	November	December	January	February	March
Rainfall in inches	4·01	28·3	15·7	1·3	1·0	*Total 50·4 inches*				
Number of rainy days	5	26	19	2	3	*Total 55 days*				
Mean max. Temp.(F.)	93·1	84·9	85·0	90·3	95·5	94·3	91·9	84·7	92·3	98·8
Mean minimum Temp. (F.)	81·9	77·6	77·0	77·3	74·5	67·9	62·7	54·9	59·8	67·3
Humidity at 18·00 hours	68	91	85	71	53	39	47	46	36	31

The usual two-year rotation was of *jowar* (*Andropogon sorghum*) and cotton. The cotton was generally manured with 10 cartloads of Farm Yard Manure once in five years. Sowing was either done by drilling or dibbling. The seed rate was 6 to 10 lb. per acre. Four to five interculturings were given with one or two weedings which ceased in October. Flowering started in mid-November, reaching the maximum in December. Joshi [1941] found that flower buds took 35 to 45 days to open into flowers and the boll maturation period varied from 61 to 78 days, as given by Patel and Mann [1928]. The average yield was 120 lb. of lint.

This investigation was undertaken as the spacing of cotton had altered considerably from the time Surti cotton was grown in this tract. Formerly, cotton was drilled at 2 ft. apart and this practice was changed in 1923-24 on the Government Agricultural Farm and cotton was dibbled at 3 ft. by 3 ft. In 1932, cultivators on their own initiative started sowing of cotton at 4, 5 and 6 ft. apart between rows and thinned to 1 to 1½ ft. as they thought that wider spacing resulted in better yields.

In order to get experimental evidence for or against this practice, experiments in two series were conducted at the Surat Farm, one from 1932 to 1937 and the other from 1939 to 1945. In the first series of experiments for six years differences in yields under different spacings did not come out to be significant, while in the second series, the yield under wider spacing came to be significantly higher than under closer spacing. This happened on both the sets a and b of experiments conducted in each series (Table II). The term wider or closer spacing at that time referred only to distance between rows.

TABLE II

Yield of seed cotton in lb. (*per acre*)

First series 1932-37			Second series 1939-1945		
Spacing in sq.ft. per plant	Mean yield		Spacing in sq.ft. per plant	Mean yield	
	Set a	Set b		Set a	Set b
3 ft. × 3 ft. = 9 sq.ft.	534	544	3 ft. × 1 ft. = 3 sq.ft.	275	367
4 ft. × 2 ft. = 8 sq.ft.	541	593	6 ft. × 2 ft. = 12 sq.ft.	441	486
4 ft. × 3 ft = 12 sq.ft.	539	528	6 ft. × 2 ft. = 12 sq.ft.	516	480
5 ft. × 2 ft. = 10 sq.ft.	524	596	6 ft. × 2 ft. = 12 sq.ft.	416	504
6 ft. × 2 ft. = 12 sq.ft.	554	585			
S.E.	32·8	59·7	C.D.	100·6	75·3
	not significant				

This difference in the results obtained in the two series could, however, be explained on the basis of studying the spacings adopted for unit area per plant rather than on the distance between rows. There was a marked difference in the closest spacing adopted in the two series. In the first series, closest spacing was 8 sq.ft. per plant while in the second series, it was only 3 sq.ft. per plant. Taking the common widest spacing of 12 sq.ft. per plant in both the series, the comparison of wide and close spacing was not similar in the two cases. The close spacing of 3 sq.ft. per plant naturally proved detrimental to the growth of the crop and decidedly lower yields were obtained than in the wide spacing even though the plant population per acre was less in the latter case. Thus, from the results obtained from these experiments, final conclusions cannot be drawn.

It was, therefore, necessary to consider the difference in spacing by the unit area provided for each plant as the efficient utilisation of the space placed at the disposal of the plant would depend on the manner in which space was distributed round about it. It appeared that the question of spacing required re-examination as it was not clear from the results obtained what was the optimum spacing for the *herbaceum* cotton grown in Gujerat.

Observations made by the senior author on the spacing experiment laid out at the farm at Surat in the 1942-43 season suggested that closely spaced crop (3 sq.ft. per plant) appeared to suffer from a deficiency of nitrogen as the growth was stunted, the leaves were smaller in size and some of the leaves had turned yellow. It was, therefore, necessary to include nitrogen as one of the treatments, in the spacing experiment. It was also considered necessary to include phosphorus and potash along with nitrogen to determine if any of these important nutrients was limiting the growth of the closely spaced crop.

The mere determination of the yields in the spacing experiment would not throw light on the physiological causes of lower yields under close spacing. It was necessary to study the growth of the crop at different stages and these growth studies should be accompanied by a study of the mineral uptake of the plant. Thus, a study of the physiology of growth and the mineral uptake may reveal the causes of lower yields under closer spacing than under wider spacing though the plant population per acre was greater in the former than in the latter.

While studying all the data obtained in these investigations, the results obtained by Crowther *et al.* [1930, 1932, 1935 to 37] in the Sudan and Egypt and by Dastur *et al.* [1943-45] in India were discussed. These are, therefore, not mentioned here.

Investigation

Details of experiments. Four factorial experiments were conducted during the period 1944-48 at the Agricultural Farm, Surat. In the first two experiments, three spacing treatments, two or three levels of nitrogen and two or three length to breadth ratios between plants under each spacing were kept as treatments. In the remaining two experiments, the effect of spacings in combination with two or three levels of nitrogen, phosphoric acid and potash was studied. Each successive experiment was modified in the light of the results obtained in the previous experiment. The

details of layout and the levels of factors studied in each experiment are given in Table III.

Table III

Details of experiments

Experiment number	Layout	Main plots	Sub-plots		
		Nitrogen × Spacing	Breadth to length ratio		
			1 : 1	1 : 2	1 : 4
I(1944-45)	6 × 6 latin square and split plot design. 36 main plots 3 sub-plots	0 — 4 sq.ft. 50 lb. — 9 sq.ft. 16 sq.ft.	24 ft. × 24ft. 36 ft. × 36 ft. 48 ft. × 48 ft.	17 ft. × 34 ft. 25 ft. × 51 ft. 34 ft. × 68 ft.	12 ft. × 48 ft. 18 ft. × 72 ft. 24 ft. × 96 ft.
	6 Replications	Main plot size gross = 58 × 72			
		sub-plot size gross = 18 × 72			
II (1945-46)	Randomised block and split plot design. 9 main plots	0 — 4 sq.ft. 50 lb. — 8 sq.ft. 100 lb. — 12 sq.ft.	24 ft. × 24 ft. 34 ft. × 34 ft. 42 ft. × 42 ft.	17 ft. × 34 ft. 24 ft. × 48 ft. 29 ft. × 58 ft.	
	2 sub-plots	Main plot size gross = 45 × 72			
	6 Replications	Sub-plot size gross = 22·5 × 72			
		Main plots	*Sub-plots*		
III (1946-47)	2^3 partially confounded first and second order interactions 8 main treatments divided into groups of 4	N × P_2O_5 × K_2O 0 lb. — 0 lb. — 0 lb. 75 lb. — 150 lb. — 150 lb.	4 sq.ft. 8 sq.ft. 12 sq.ft.		
	4 sub-plots	Sub-plot size Net = s1 = s2 = s3 = 504 sq.ft.			
	4 Replications	s4 = 480 sq.ft.			
IV (1947-48)	3^4 partially confounded 2nd order interaction	N × P_2O_5 × K_2O × Spacing 0 — 0 — 0 — 8 sq.ft. 50 lb. — 50 lb. — 50 lb. — 12 sq.ft. 100 lb. — 100 lb. — 100 lb. — 16 sq.ft.			
	81 treatments divided into groups of 9, 4 replications	Plot size net = 432 sq.ft.			

Manurial doses are in pounds per acre.
Spacings are in square feet per plant.
Due to different breadth to length ratios and spacings, the net sub-plot size in first three experiments could not be the same, so yield of each sub-polt was calculated per acre basis, before it was statistically analyzed.

Observations recorded

In all experiments the dry weights of different parts were determined at fruiting period i.e., in January on equal area basis from all treatments. Area sampled was 64 sq.ft., 72 sq.ft., 48 sq.ft. and 48 sq.ft. in experiment I, II, III and IV respectively as under :

Experiment No. I		Experiment No. II		Experiment No. III		Experiment No. IV	
Spacing sq.ft.	Plants sampled	Spacing sq.ft.	Plants sampled	Spacing sq.ft.	Plants sampled	Spacing sq ft.	Plants sampled
4	16	4	18	4	12		
9	7	8	9	8	6	8	6
16	4	12	6	12	4	12	4
				16	3	16	3

In the third experiment progressive growth data at monthly interval were collected for each treatment for which each plot was divided into two halves reserving one half at random for progressive data and other one for final yield. The plants from 48 sq.ft. were sampled at random each month and final height per plant (average of 10 plants) dry weight, percentage increase in height and dry weight, relative growth rate, net assimilation rate, etc., were derived from these data. Some were used for analysing chemical contents.

The rate of flowering in experiments third and fourth was studied by recording daily flowers opened from 96 sq.ft. area from two replications, out of which half the numbers (48 sq.ft.) were utilised for taking weekly boll opening to study boll number, weight of *kapas* per boll, earliness, ginning percentage, weight of seed and setting percentage of flowers to bolls, and other half final chemical analysis.

All these data were statistically analyzed by method appropriate to the layout. The critical difference of each character so studied is given in each respective table.

The chemical analysis of the leaves of plants at the time of maximum dry weight attained by the crop was made for nitrogen, potash, phosphorus and lime contents from the first three experiments.

The effect of spacing on progressive growth

The cumulative increase in height at different stages of growth under four spacings in the experiment conducted in 1946-47 is given in Fig. 1. As potash was not found to produce any effect on the vegetative growth of the plant, the average values of control, nitrogen, phosphorus and nitrogen plus phosphorus are plotted separately for each spacing. No effect of spacing was visible on the nature of the growth curve but the rise in height became more steep as the spacing became wider. A rapid increase in height was visible in the manured plants from mid-August and in the control plants, from mid-September. The plants continued to gain in height for a month longer in the wider spacing than under closer spacing. Nitrogen plus phosphorus proved to be better for extension growth than nitrogen alone. The maximum percentage of total increase in height in the first two close spacings was attained a month earlier in the manured plants than in the unmanured plants while there was no such difference between unmanured plants in the two spacings (Fig. 2).

The relative growth rate and net assimilation rate were derived from the dry weight data and it was found that the relative growth rate and net assimilation rate reached their maximum in the month of September after which both declined rapidly on account of rapid accumulation of dry matter (Figs. 3 and 4). Spacing was not found to produce any effect on these inherent characters of growth. Nitrogen was, however, found to produce a marked effect. It increased both the relative growth rate and the net assimilation rate during the first three months after sowing under all spacings.

Breadth to length ratio

The different breadth to length ratios (from 1 : 1 to 1 : 4) tried in each spacing in first two experiments did not differ significantly in any character which proved

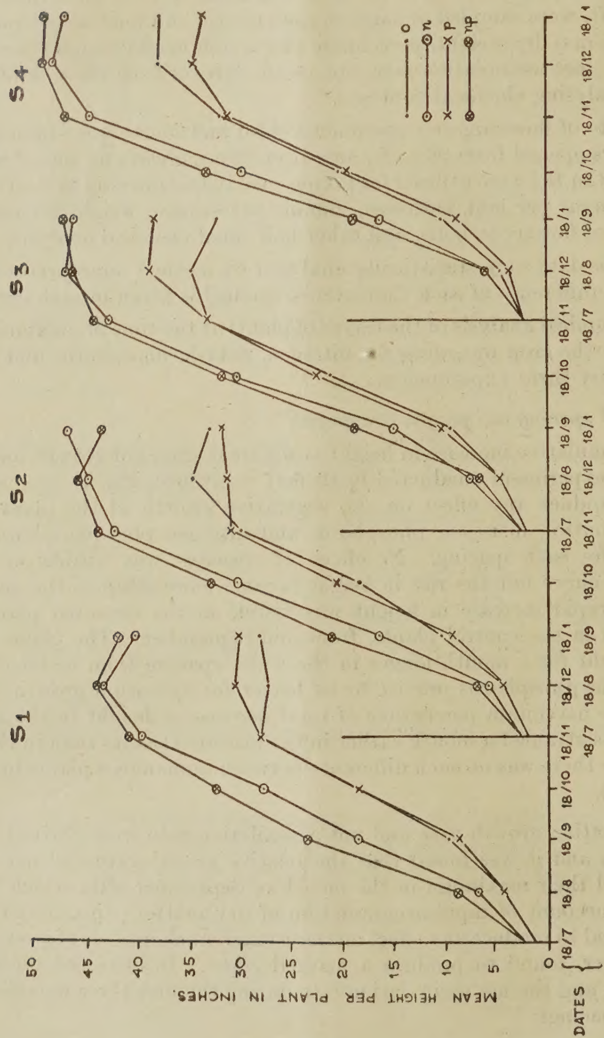

FIG. 1. Mean height per plant

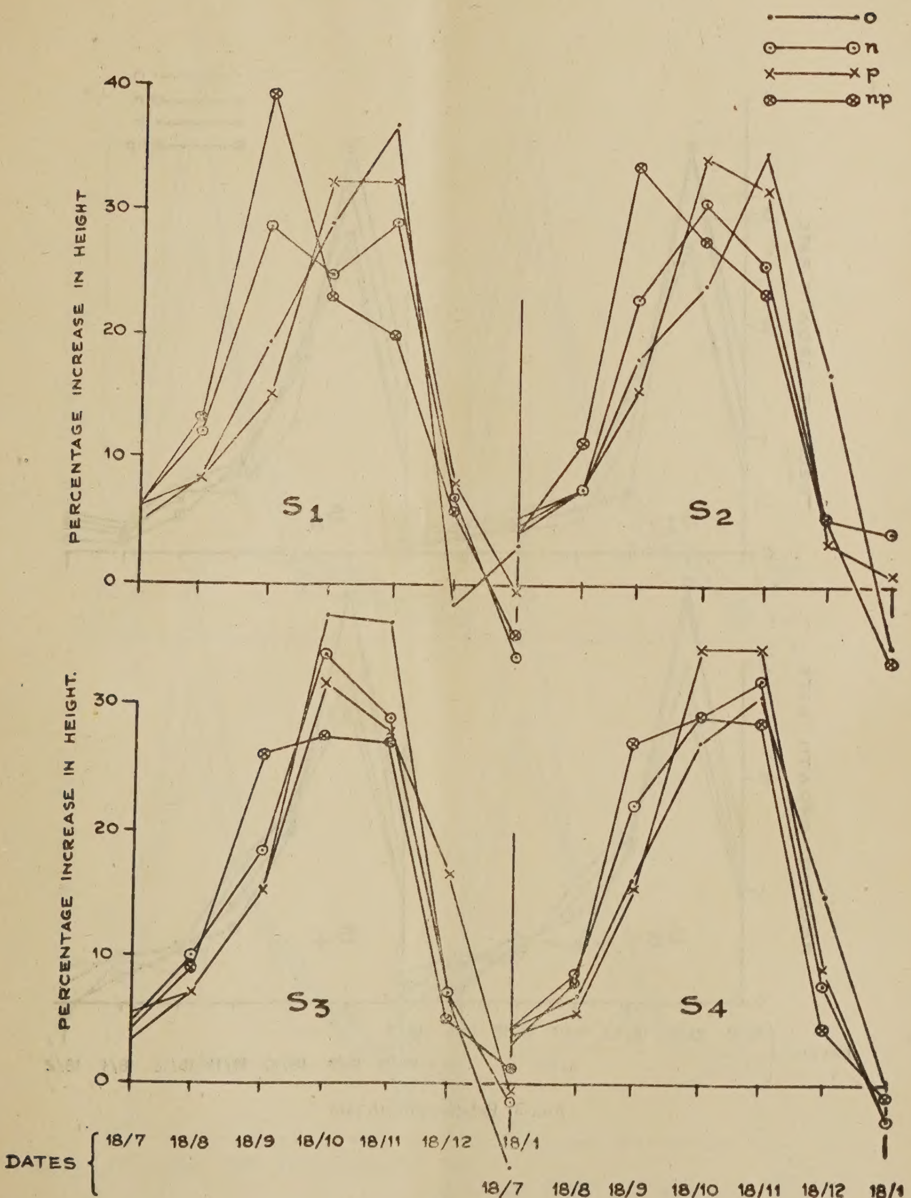

Fig. 2. Percentage increase in height

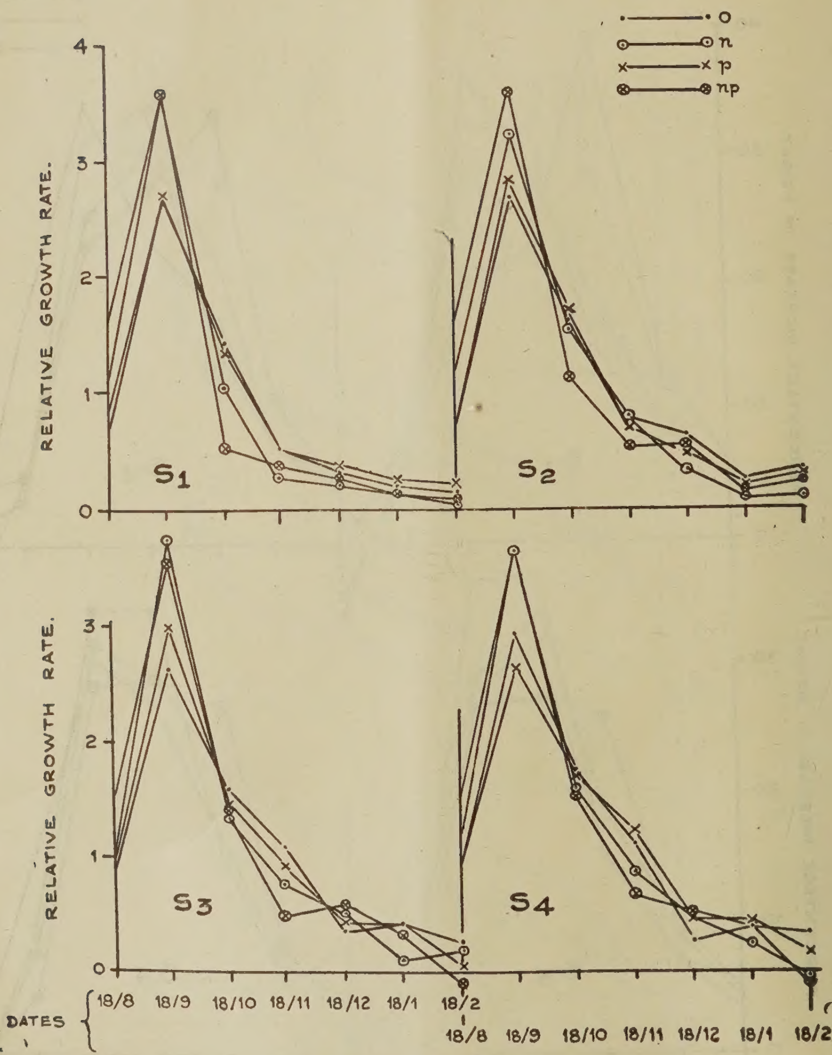

FIG. 3. Relative growth rate

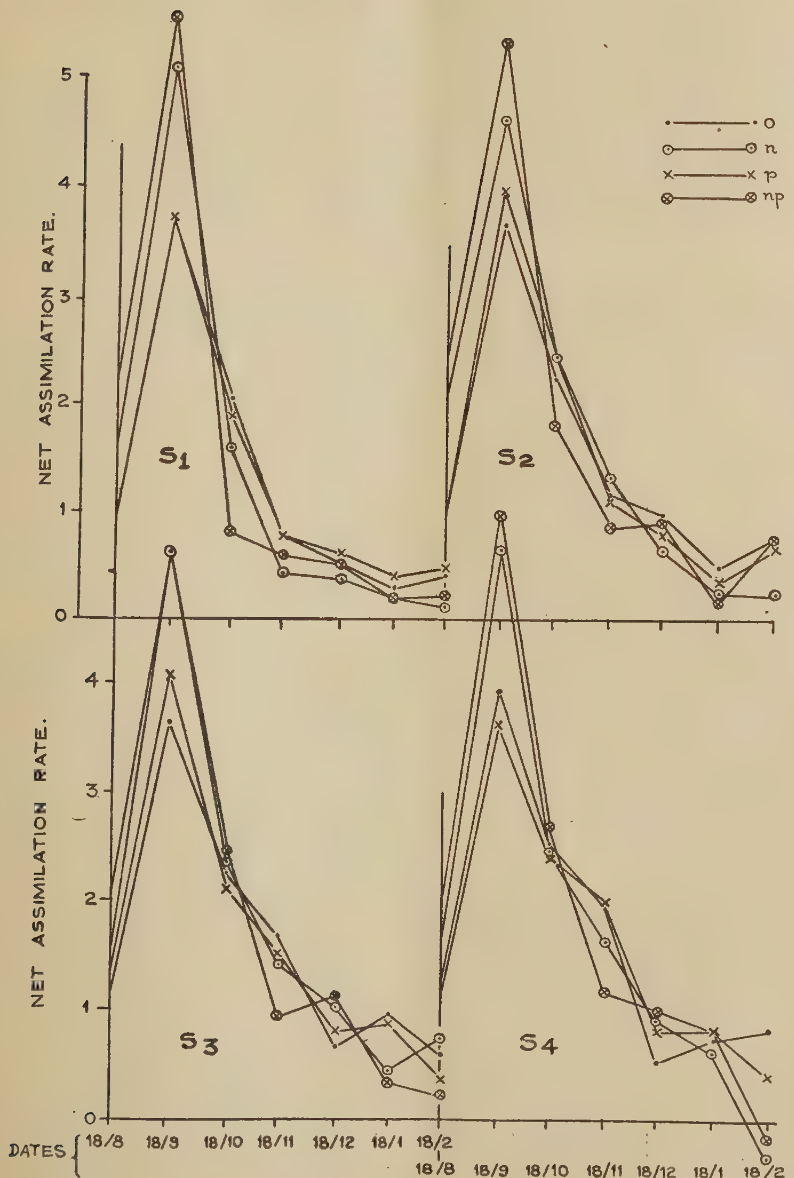

Fig. 4. Net assimilation rate

that the distribution of the spacing round about the plant within this range had no effect. The effects of this factor are not discussed here.

The effect on final height and dry weight

A study of the results of final height and the dry weight per plant and per square yard under different spacings in the four experiments indicated that the height per plant significantly increased as the spacing became wider (Table IV). The extension growth was greater under wider spacing than under closer spacing.

TABLE IV

(a) *Final height per plant in cm.*

Spacing per plant	Experiment I (1944-45)				Spacing per plant	Experiment II (1945-46)			
	4 sq.ft.	9 sq.ft.	16 sq.ft.	Mean C.D. 3·80		4 sq.ft.	8 sq.ft.	12 sq.ft.	Mean C.D. 10·09
Control	57·0	69·2	85·2	*70·1*	Control	64·1	75·6	81·6	*73·8*
50 lb. N	70·9	84·9	100·3	*85·4*	50 lb. N	70·2	81·6	91·4	*81·1*
					100 lb. N	74·4	84·3	93·0	*83·9*
Mean C.D. (4·66)	*63·9*	*76·5*	*92·8*		*Mean* (C.D. 10·09)	*69·6*	*80·5*	*88·7*	

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. 2·98		8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean 0·74
Control	28·8	32·2	35·0	35·3	*32·8*	Control	30·2	32·5	35·0	*32·6*
						50 lb. N	38·1	41·3	44·0	*41·2*
75 lb. N	40·8	46·7	46·2	*47·8*	45·2	100 lb. N	42·3	44·8	46·6	*44·5*
Mean C.D. (2·28)	*34·8*	*39·0*	*40·7*	*41·5*	39·0	*Mean* C.D. (0·74)	*36·9*	*39·5*	*41·9*	*39·4*

(b) *Average dry weight per plant in grams*

Spacing per plant	Experiment I (1944-45)				Spacing per plant	Experiment II (1945-46)			
	4 sq.ft.	9 sq.ft.	16 sq.ft.	Mean C.D. (10·59)		4 sq.ft.	8 sq.ft.	12 sq.ft.	Mean C.D. (10·27)
Control	31·4	51·8	84·0	*55·7*	Control	38·8	64·8	94·5	*65·9*
50 lb. N	44·1	89·1	152·7	*95·3*	50 lb. N	47·2	87·2	132·4	*88·9*
					100 lb. N	59·9	97·3	144·3	*100·5*
Mean C.D. (12·94)	*37·7*	*70·4*	*118·4*		*Mean* C.D. (10·27)	*48·5*	*83·1*	*123·7*	

(c) *Average dry weight per sq.yd. in gm.*

Spacing per plant	4 sq.ft.	9 sq.ft.	16 sq.ft.	Mean C.D. (8·14)	Spacing per plant	4 sq.ft.	8 sq.ft.	12 sq.ft.	Mean C.D. (12·32)
Control	70·6	51·8	47·2	*56·5*	Control	86·7	72·9	70·9	*76·8*
50 lb. N	99·2	89·1	85·9	*91·4*	50 lb. N	106·2	98·1	99·3	*101·2*
					100 lb. N	134·8	109·4	108·2	*117·5*
Mean C.D. (10·00)	*84·9*	*70·4*	*66·6*		*Mean* C.D. (12·32)	*109·2*	*93·5*	*92·8*	

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (25·5)		8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (6·76)
Control	118	120	117	114	*118*	Control	74	74	76	*75*
75 lb. N	231	275	250	227	*246*	50 lb. N	173	162	172	*169*
						100 lb. N	233	204	202	*216*
Mean C.D. (17·6)	*175*	*194*	*184*	*170*	*182*	*Mean* C.D. (6·76)	*160*	*150*	*150*	*153*

Similarly, the dry weight per plant also significantly increased as the spacing became wider. Thus plants grew more vigorously under wide spacing than under close spacing. This difference was not entirely caused by a deficiency of nitrogen under closer spacing as the interaction between spacings and nitrogen did not turn out to be significant. Nitrogen significantly increased the height per plant and the dry weight per plant under all spacings so that the differences due to spacings remained unaltered. The maximum height and dry weight and dry weight per plant were attained under the widest spacing. Thus, besides nitrogen, there was some other factor that operated in producing the differences in growth under different spacings even in the presence of nitrogen.

Though the dry weight per plant was highest under widest spacing, the dry weight per unit area came out to be highest under closest spacing. Individually the plant was smaller, but its greater number per unit area put up the dry weight per square yard. Though the dry matter production under close spacing was higher per unit area this was not true of the reproductive growth as shown below.

The effect of spacing on reproductive growth

Close spacing was found to reduce the flower production per unit area though it increased the dry weight and that may be due to the greatly reduced number of bearing points on account of reduction in height under closer spacing (Table V). The maximum number of flowers was produced under wider spacing (16 sq.ft. per

plant), except in Experiment IV where maximum was reached under the spacing of 12 sq. ft. per plant when manured with 100 lb. nitrogen. Thus with a higher dose of nitrogen than 50 lb. N the production of flower was equally high in the two wide spacings. Nitrogen significantly increased flower production under all spacings but increase due to 50 lb. N was highest in 16 sq.ft. while by application of 100 lb. N the increase was highest in 12 sq.ft. spacing. There was thus a reduction in flower production per unit area when the crop was closely spaced.

TABLE V

Number of flowers per sq. yd.

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (13·5)		8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (4·27)
Control	43·2	46·7	46·1	50·1	*46·6*	Control	32·7	38·6	39·8	*36·7*
75 lb. N	71·6	83·1	87·0	87·6	*82·4*	50 lb. M	60·3	66·0	75·7	*67·3*
						100 lb. N	85·6	102·5	97·6	*95·2*
Mean C.D. (8·90)	*57·4*	*64·9*	*66·6*	*68·9*	*64·5*	*Mean* C.D. (4·27)	*59·5*	*69·0*	*70·7*	*66·4*
							Interaction C.D. 7·41			

Though there was a reduction in flower production under close spacing there was no clear evidence of a decrease or an increase in the setting percentage of flowers into bolls (Table VI) as the spacing became wider.

TABLE VI

Setting percentage of flowers into bolls

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (4·73)		8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (1·38)
Control	44·5	48·8	48·2	48·3	*47·5*	Control	40·2	40·7	38·9	*39·9*
75 lb. N	39·2	43·2	42·4	42·8	*41·9*	50 lb. N	37·9	40·6	36·9	*38·5*
						100 lb. N	36·0	34·2	32·4	*34·2*
Mean C.D. (2·78)	*41·9*	*46·0*	*45·3*	*45·6*	*44·7*	*Mean* C.D.(1·38)	*38·0*	*38·5*	*36·1*	*37·5*

The setting percentage was lower under the closest spacing of 4 sq.ft. per plant in Experiment III than under wider spacing. The setting percentage was also low in the widest spacing in Experiment IV. But nitrogen had significantly decreased the setting percentage in both the experiments indicating that nitrogen though it increased flower production did not increase the setting percentage of flowers into bolls.

The boll production per unit area under close and wide spacings did not show consistent trends. In the expeirments numbers I and II the boll number per unit area did not differ significantly in different spacings. It was nearly the same in the three spacings. In the Experiment No. III, the boll number per sq.yd. was significantly less in the closest spacings but there was no significant difference in the boll production in the remaining three spacings (Table VII) though there was a trend in favour of wider spacing. In the Experiment IV the boll production was significantly less in the medium spacing of 8 sq.ft. per plant than in wider spacing. Thus boll production remained the same under close and wide spacings in some cases while in other cases there was a small increase in boll number per square yard under wide spacings.

TABLE VII

Number of bolls per square yard

Spacing per plant	Experiment I (1944-45)				Spacing per plant	Experiment II (1945-46)			
	4 sq.ft.	9 sq.ft.	16 sq.ft.	Mean C.D. (2·42)		4 sq.ft.	8 sq.ft.	12 sq.ft.	Mean C.D. (2·23)
Control	18·4	17·5	18·5	*18·2*	Control	16·1	18·0	17·5	17·2
50 lb. N	21·4	22·2	22·3	*22·0*	50 lb. N	17·8	19·9	19·6	19·1
					100 lb. N	21·6	20·7	20·9	21·0
Mean C.D. (3·13)	*19·9*	*19·8*	*20·4*		*Mean* C.D. (2·23)	*18·5*	*19·6*	*19·3*	

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (3·56)		8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (1·58)
Control	18·4	21·9	21·8	24·1	*21·6*	Control	13·0	15·0	15·0	*14·3*
75 lb. N	27·2	35·6	36·8	36·6	*34·0*	50 lb. N	22·7	26·4	27·6	*25·6*
						100 lb. N	30·5	34·9	31·5	*32·3*
Mean C.D. (3·39)	*22·8*	*28·8*	*29·3*	*30·4*	*27·8*	*Mean* C.D. (1·58)	*22·1*	*25·6*	*24·7*	

Nitrogen significantly increased the boll production in all experiments but the magnitude of increase was small in the first two experiments and large in the next two experiments.

Though the results of boll production per unit area varied in different experiments and did not show consistent trends in favour of wider spacing, the results of yields of seed cotton per acre were in favour of wider spacing (Table VIII). The yield increased even in the unmanured condition as the spacing became wider (except in

Experiment I). The same was true of the manured crop. The main effect of spacing on yield was significant in all experiments except in experiment No. II. The greatest and significant increase occurred from the closest spacing of 4 sq.ft. per plant to 8 sq.ft. per plant in Experiment III and the yields tended to be equal in the last two spacings. The increase in yield under wider spacings with application of 100 lb. N was, however, not significant in Experiment II the reason for which is explained later.

TABLE VIII

Yield of seed cotton in lb. per acre

Spacing per plant	Experiment I (1944-45) 4 sq.ft.	9 sq.ft.	16 sq.ft.	Mean C.D. (34·38)	Spacing per plant	Experiment II (1945-46) 4 sq.ft.	8 sq.ft.	12 sq.ft.	Mean C.D. (45·74)
Control	327	326	324	*326*	Control	323	355	357	*345*
50 lb. N	378	424	484	*429*	50 lb. N	346	378	397	*374*
					100 lb. N	416	417	425	*419*
Mean C.D. (42·10)	*353*	*375*	*404*	*376*	*Mean* C.D. (45·74)	*362*	*384*	*393*	*379*
	Interaction C.D. 72·8					Interaction C.D. 79·2			

Spacing per plant	Experiment III (1946-47) 4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (55·3)	Spacing per plant	Experiment IV (1947-48) 8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (23·4)
Control	314	374	401	427	*379*	Control	243	297	320	*288*
75 lb. N	557	658	677	685	*644*	50 lb. N	484	579	641	*568*
						100 lb. N	643	700	691	*678*
Mean C.D. (40·6)	*436*	*516*	*539*	*556*	*512*	*Mean* C.D. (23·4)	*457*	*525*	*551*	*511*
							Interaction C.D. 40·5			

Application of nitrogen significantly increased the yields in all the four experiments, indicating its deficiency for the cotton crop in the soils of Surat. All the spacings were found to be benefited by application of 50 lb. N or 75 lb. N, showing that extra nitrogen was needed even for the widely spaced crop. But when still higher doses of nitrogen were applied, as in experiment No. II and IV, the increase produced by 100 lb. nitrogen over 50 lb. nitrogen became less as the spacing became wider. Thus the yields, when 100 lb. nitrogen was applied, tended to be nearly equal under close, medium and wide spacings. It, therefore, appeared that closely spaced crop generally suffered more from a deficiency of nitrogen than widely spaced crop and all the nitrogen requirements of the crop under close spacing were not met when 50 lb. or 75 lb. nitrogen were applied. But when still higher doses of nitrogen

were applied, the closely spaced crop obtained all its requirements and there was further increase in yield. The case was, however, different for the widely spaced crop which was not benefited to the same extent by the application of 100 lb. nitrogen. Nitrogen applied probably became in excess of its requirements and remained unutilized. Thus closely spaced crop required higher doses of nitrogen than widely spaced crop in order to produce the same yield as in the case of wider spacings. This conclusion was supported by the dry weight produced per unit area by the crop under different levels of nitrogen (Table IX).

Table IX

Dry weight per sq.yd. in gm.

Spacing per plant	Experiment II (1945-46)				Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	Mean C.D. (12·32)		8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (6·76)
Control	86·7	72·9	70·9	*76·8*	Control	74	74	76	*75*
50 lb. N	106·2	98·1	99·3	*101·2*	50 lb. N	173	162	172	*169*
100 lb. N	134·8	109·4	108·2	*117·5*	100 lb. N	233	214	202	*216*

There was nearly equal increase in dry weight per square yard by the application of 50 lb. N under all spacings, but when 100 lb. nitrogen was applied, the further increase in dry weight over the dry weight produced by application of 50 lb. N became less as the spacing became wider. Thus, extra nitrogen added was not utilized for growth under wider spacing to the same extent as in the case of closely spaced crop.

Thus nitrogen appeared to be deficient in the soils at Surat. When the crop was widely spaced, better vegetative and reproductive growth occurred due to lesser competition for that nutrient and wider spacing gave slightly better yields than close spacing. When 50 lb. or 75 lb. N was applied nitrogen proved to be more or less adequate for close spacing and appeared to be in excess for wide spacing. Even then the trends were slightly in favour of wide spacing. Twelve square feet per plant in the presence of 100 lb. N gave the maximum yield.

Boll weight

Wider spacing was also found to produce a bigger boll size, as can be seen from the results. The boll weight significantly increased in some experiments as the spacing became wider while in other experiments, though the trends were in favour of wider spacing, the main effect of spacing did not come out to be significant (Table X). Thus bigger boll size under wider spacing tended to increase the yield in that spacing even though the boll production per unit area was not found to increase in some of the experiments. It, therefore, appeared that a small increase in the boll size occurred under wider spacing, resulting in slightly better yields.

TABLE X

Weight of seed cotton per boll in gm.

Spacing per plant	Experiment I (1944-45) 4 sq.ft.	9 sq.ft.	16 sq.ft.	Mean C.D. (0·048)
Control	1·85	1·95	1·97	*1·92*
50 lb. N	1·82	1·88	2·00	*1·90*
Mean C.D. (0·058)	*1·83*	*1·91*	*1·98*	

Spacing per plant	Experiment III (1946-47) 4 sq.ft.	8 sq.ft.	12 sq.ft.	Mean 16 (0·057)
Control	2·25	2·30	2·37	*2·31*
50 lb. N	2·15	2·24	2·27	*2·22*
100 lb. N	2·19	2·31	2·24	*2·25*
Mean C.D. (0·057)	*2·20*	*2·28*	*2·29*	

Spacing per plant	Experiment III (1946-47) 4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (0·18)
Control	1·98	2·13	2·10	2·00	*2·05*
75 lb. N	2·00	2·07	2·18	2·18	*2·11*
Mean C.D. (0·15)	*1·99*	*2·10*	*2·14*	*2·09*	

Spacing per plant	Experiment IV (1947-48) 8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (0·06)
Control	2·05	2·18	2·19	*2·17*
50 lb. N	2·37	2·49	2·54	*2·47*
100 lb. N	2·44	2·52	2·51	*2·49*
Mean C.D. (0·06)	*2·29*	*2·40*	*2·45*	

Nitrogen was not found to affect the boll weight. In two experiments it did not increase the boll size while in one experiment a significant increase in boll size was found. This finding was in contradiction to the finding in the Punjab of Dastur and Mukhtar Singh [1944] who found a consistent increase in boll weight when nitrogen was applied to nitrogen deficient light sandy lands.

Crop arrival

Another interesting finding of this investigation was that the crop arrival was delayed as the spacing became wider. Under close spacing the crop manured earlier by 10 to 20 per cent as shown below in Table XI. Similarly the application of nitrogen made the crop significantly early in ripening under Gujerat conditions. Under Punjab conditions the application of nitrogen tended to delay ripening.

TABLE XI

Percentage of total crop picked in the first picking

Spacing per plant	Experiment I (1944-45) 4 sq.ft.	9 sq.ft.	16 sq. ft.	Mean C.D. (1·59)
Control	73·7	67·3	57·3	*66·0*
50 lb. N	84·0	81·3	76·7	*80·7*
Mean C.D. (1·95)	*78·9*	*74·3*	*66·9*	*73·4*

Spacing per plant	Experiment IV (1947-48) 8 sq. ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (1·67)
Control	52·8	52·0	52·1	*52·3*
50 lb. N	65·7	66·1	64·6	*65·5*
100 lb. N	68·9	67·7	59·3	*65·3*
Mean C.D. (1·67)	*62·5*	*61·9*	*58·7*	*61·0*

Interaction C.D. = 2·88

Fruiting coefficient

As the reproductive growth was suppressed while the total dry matter production increased or remained nearly the same in the close spacing, the fruiting coefficient was found to increase as the spacing became wider (Table XII). Thus the efficiency of the crop to produce seed cotton increased progressively as the spacing became wider.

TABLE XII

Fruiting coefficient

Spacing per plant	Experiment I (1944-45)				Spacing per plant	Experiment III (1946-47)				
	4 sq.ft.	9 sq.ft.	16 sq.ft.	Mean C.D. (0·044)		4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (0·026)
Control	0·48	0·66	0·79	*0·64*	Control	0·25	0·30	0·33	0·36	*0·31*
50 lb. N	0·40	0·46	0·54	*0·47*	75 lb. N	0·23	0·23	0·26	0·29	*0·25*
Mean C.D. (0·053)	*0·44*	*0·56*	*0·67*		*Mean* C.D. (0·038)	*0·24*	*0·27*	*0·29*	*0·32*	

Though there was an increase in total yield of seed cotton per acre when nitrogen was applied the results given above indicated that the quantity of seed cotton produced per unit dry matter had actually decreased. It indicated that the increase in yield of seed cotton due to nitrogen was not in the same proportion as the increase in total dry weight. Thus the extra nitrogen added to the soil produced more of the vegetative growth than of the seed cotton. Thus the fruiting coefficient became less when nitrogen was applied.

The effect of phosphorus on growth and yield

The application of 150 lb. P_2O_5 appeared to increase the dry matter per unit area but that increase did not reach the level of significance in Experiment III (Table XIII).

TABLE XIII

Dry weight per sq.yd. in gm.

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (25·5)		8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (6·76)
Control	163	199	187	159	172	Control	153	143	151	149
150 lb. P_2O_5	186	216	183	176	190	50 lb. P_2O_5	161	150	147	153
						100 lb. P_2O_5	166	157	150	158

There was no interaction between spacing and phosphoric acid. The addition of phosphoric acid increased the dry weight in Experiment IV but the difference between control and a double dose of phosphoric acid was alone significant.

Phosphorus was also found to increase significantly the flower production in Experiment No. III (Table XIV) but that was not the case in Experiment IV (Table XIV).

Table XIV

Total flowers produced per sq. yd.

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (13·5)		8 sq. ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (4·27)
Control	50	60	56	63	57	Control	58·6	68·2	71·4	66·1
150 lb. P_2O_5	65	70	76	74	71	50 lb. P_2O_5	60·6	68·7	68·8	66·1
						100 lb. P_2O_5	59·3	70·2	71·7	67·1

Similar results were obtained for boll production and yield in Experiment III. There was a significant increase in boll production in Experiment III but that was not the case in Experiment IV (Table XV).

Table XV

Total number of bolls per sq.yd.

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (3·56)		8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (1·58)
Control	21	26	27	32	27	Control	22·0	24·6	25·3	24·0
150 lb. P_2O_5	34	28	35	33	31	50 lb. P_2O_5	22·9	25·7	23·8	24·2
						150 lb. P_2O_5	21·3	26·4	25·0	24·2

Yield in lb. per acre

Spacing per plant	Experiment III (1946-47)					Spacing per plant	Experiment IV (1947-48)			
	4 sq.ft.	8 sq.ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (55·3)		8 sq. ft.	12 sq.ft.	16 sq.ft.	Mean C.D. (1·58)
Control	420	501	507	539	492	Control	465	520	545	510
150 lb. P_2O_5	540	531	571	573	531	50 lb. P_2O_5	475	517	557	516
						100 lb. P_2O_5	430	539	549	506

Similarly the increase in yield due to phosphorus was almost uniform in the different spacings in Experiment No. III but the main effect of phosphorus did not reach the level of significance. In Experiment IV there was no increase in yield recorded by application of double dose of phosphoric acid.

The above results did not, however, provide any indication that phosphoric acid was playing any part in producing better yields of seed cotton when the crop was widely spaced.

The effect of potash on growth and yield

As no effects of application of potash on either the vegetative or reproductive growth were observed, these results are not discussed here.

The effect of phosphoric acid and potash in combination with nitrogen on yield

Phosphorus or potash in combination with nitrogen increased the yields and the interactions of nitrogen with phosphoric acid and of nitrogen with potash came out to be appreciable though they did not reach the level of significance in the Experiment III (Table XVI).

TABLE XVI

Yield of seed cotton in lb. per acre

	n × p interaction				n × k interaction		
	Control	75 lb. N	Mean C.D. (55·3)		Control	75 lb. N	Mean C.D. (55·3)
Control	384	599	*492*	Control	417	619	*518*
150 lb. P_2O_5	374	689	*531*	150 lb. K_2O	340	670	*505*
Mean C.D. (55·3)	*379*	*644*	*511*	*Mean* C.D. (55·3)	*379*	*644*	*511*

In Experiment IV where three levels of nitrogen, potash and phosphoric acid were kept as treatments the application of 50 lb. P_2O_5 in combination with 100 lb. nitrogen increased significantly the yield but there was no further increase in yield when higher dose of phosphoric acid was used (Table XVII).

TABLE XVII

Yield of seed cotton in lb. per acre

Interaction C.D. 78·6	Interaction C.D. 78·6			
	Control	50 lb. P_2O_5	100 lb. P_2O_5	Mean C.D. (23·4)
Control	291	277	292	*288*
50 lb. N	588	571	544	*568*
100 lb. N	652	700	682	*678*
Mean C.D. (23·4)	*510*	*519*	*506*	*511*
	Interaction C.D. 40·5			

Thus, from both the experiments, there was an indication that phosphorus when used in combination with nitrogen further increased the yield but this finding required further confirmation.

There was no such effect of potash on yield when it was used in combination with nitrogen in Experiment IV. It may be mentioned that these conclusions are derived from the results of two experiments only.

Chemical analysis of the leaves

The leaves of plants collected from all the sub-plots of the first three experiments at the bolling stage (middle of January) were analyzed for nitrogen, phosphoric acid, potash and lime. It was found that the concentration of nitrogen was higher in the leaves of the widely spaced crop than under close spacing, indicating a greater depletion of nitrogen from the leaves of the closely spaced crop. Thus there was another evidence to show that nitrogen was acting as a limiting factor when plants were closely spaced.

TABLE XVIII

Percentage of nitrogen in leaves

Spacing per plant	Experiment I (1944-45)				Spacing per plant	Experiment II (1945-46)			
	4 sq. ft.	9 sq. ft.	16 sq. ft.	Mean C.D. (0·132)		4 sq. ft.	8 sq. ft.	12 sq. ft.	Mean C.D. (0·071)
Control	2·06	2·37	2·46	*2·30*	Control	1·75	1·76	1·88	*1·80*
50 lb. N	2·30	2·83	2·89	*2·67*	50 lb. N	1·69	1·80	1·91	*1·80*
					100 lb. N	1·71	2·05	2·16	*1·97*
Mean C.D. (0·165)	*2·18*	*2·60*	*2·68*	..	Mean C.D. (0·071)	*1·72*	*1·87*	*1·98*	..

Date	Experiment III (1946-47)				
	4 sq. ft.	8 sq. ft.	12 sq. ft.	16 sq. ft.	C.D.
18 December 1946	*2·21*	*2·34*	*2·43*	*2·47*	*0·084*
18 January 1947	*1·81*	*1·89*	*2·01*	*2·05*	*0·073*
18 February 1947	*1·58*	*1·64*	*1·74*	*1·76*	*0·059*

The effect of spacing on nitrogen content was thus significant in all the experiments. In Experiment III the leaves were analyzed every month and the trends in favour of wider spacing were quite clear during fruiting months. There was also a marked fall in the nitrogen content as the season advanced.

Manuring with nitrogen increased the nitrogen concentration of the leaves under all spacings and this increase in concentration of nitrogen was more in the widely spaced crop than under closer spacing. Thus application of nitrogen was not able to equalise the nitrogen concentration of the leaves under different spacings. It

was pointed out before that application of nitrogen did not produce equal yields under different spacings and the results of chemical analysis provided an explanation for the slightly higher yields under wider spacings under Surat conditions.

Similarly, the leaves of widely spaced crop showed a higher concentration of potash than the leaves of plants under close spacing, indicating their greater availability under wide spacing. There was, however, no consistent increase in the concentration of potash by manuring with nitrogen just as was the case with nitrogen concentration. The effect of spacing on potash content was also not significant.

TABLE XIX

Percentage of potash in the leaves

Spacing per plant	Experiment I (1944-45)				Spacing per plant	Experiment II (1945-46)			
	4 sq. ft.	9 sq. ft.	16 sq. ft.	Mean C.D. (0·135)		4 sq. ft.	8 sq. ft.	18 sq. ft.	Mean C.D. (0·243)
Control	2·34	2·45	2·54	*2·44*	Control	2·48	2·47	2·41	*2·45*
50 lb. N	2·54	2·73	2·89	*2·72*	50 lb. N	2·26	2·64	2·55	*2·48*
					100 lb. N	2·35	2·29	2·47	*2·37*
Mean C.D. (0·165)	*2·44*	*2·59*	*2·72*	..	*Mean* C.D. (0·243)	*2·36*	*2·47*	*2·48*	..

Percentage of lime in the leaves

Spacing per plant	Experiment I (1944-45)				Spacing per plant	Experiment II (1945-46)			
	4 sq. ft.	9 sq. ft.	16 sq. ft.	Mean C.D. (0·162)		4 sq. ft.	8 sq. ft.	12 sq. ft.	Mean C.D. (0·314)
Control	4·19	4·47	4·53	4·39	Control	4·70	4·44	4·40	4·51
50 lb. N	4·55	4·68	4·93	4·72	50 lb. N	4·78	4·88	4·58	4·75
					100 lb. N	4·99	4·60	4·78	4·79
Mean C.D. (0·200)	*4·37*	*4·58*	*4·73*	..	*Mean* C.D. (0·314)	*4·82*	*4·64*	*4·59*	..

Percentage of phosphoric acid in the leaves

Spacing per plant	Experiment I (1944-45)				Spacing per plant	Experiment II (1945-46)			
	4 sq. ft.	9 sq. ft.	16 sq. ft.	Mean C.D. (0·051)		4 sq. ft.	8 sq. ft.	12 sq. ft.	Mean C.D. (0·057)
Control	0·602	0·607	0·632	*0·62*	Control	0·73	0·69	0·70	*0·71*
50 lb. N	0·747	0·719	0·714	*0·73*	50 lb. N	0·70	0·75	0·65	*0·70*
					100 lb. N	0·69	0·70	0·56	*0·65*
Mean C.D. (0·062)	*0·67*	*0·66*	*0·67*	..	*Mean* C.D. (0·057)	*0·71*	*0·71*	*0·64*	..

The leaves of widely spaced crop did not show consistently higher lime and phosphoric acid concentrations than the leaves of closely spaced crop. There was significant increase in lime content as the spacing became wider but that was not found to be the case in the second experiment. Manuring was, however, found to increase the lime content of the leaves in both experiments.

Conclusions

The results of this investigation have explained the physiological and chemical factors associated with lower yields obtained when the crop was closely spaced. The close spacing of three or four square feet per plant was found to depress the reproductive growth though no such depressing effect was visible on the vegetative growth as measured by the dry weight produced per unit area. Close spacing significantly reduced the height, flower and boll production and yield. As the dry matter produced per unit area remained unaffected while the yields of seed cotton were reduced the efficiency of seed cotton production as measured by fruiting coefficient was much lessened under close spacing. Physiologically close spacing was, therefore, unsuitable under Gujerat conditions.

The medium spacing of 8 sq. ft. or 9 sq. ft. per plant proved less disadvantageous for the reproductive growth than the close spacing of 4 sq. ft. per plant. Though there was an all-round increase in the reproductive growth, the yields were still lower than under still wider spacing of 12 sq. ft. or 16 sq. ft. per plant.

Twelve square feet per plant proved to be an optimum spacing as further increase in spacing did not further increase the reproductive growth to such an extent as to give higher yields per acre. Height, flower and boll production and finally the yield of *kapas* were significantly higher than under close spacings even though total dry matter produced per unit area was significantly less. The fruiting coefficient was, therefore, high, resulting in a higher efficiency for production of seed cotton. The wider spacing incidentally possessed also other advantages from a cultivator's point of view. There was rapidity in sowing, lesser seed rate and ease in interculturing. Wide spacing was, however, found to cause a slight delay in crop arrival as compared with closer spacing as was found by Ludwig [1931] and Crowther [1937], but that did not seem to be of any great disadvantage under Gujerat conditions. The early maturity of the crop under close spacing was not caused by the early setting in of the flowering phase, as was found to be the case in *hirsutum* cottons by Hall and Armstrong [1920] and Buie [1928].

The different spacings did not appear to produce any effect on the inherent growth characters of the cotton plant such as the relative growth rate or the net assimilation rate.

The chemical analysis of the leaves at the fruiting stage revealed that greater availability of nitrogen under wider spacing than under close spacing appeared to be associated with better reproductive growth and higher yield. Although lesser availability of nitrogen under close spacing reduced the height, it did not decrease the production of dry matter per unit area. It only reduced the reproductive growth. This conclusion was confirmed by the study of the effect of application

of nitrogen on the growth of the crop and the nitrogen concentration of the leaves. Its application was found to increase significantly extension growth, production of dry matter, flower and boll production, boll weight and yield. It also increased the nitrogen concentration in the leaves under all spacings. Even then nitrogen application up to a limit of 50 lb. to 75 lb. N per acre did not either equalize the yields or the nitrogen contents of the leaves under three or four different spacings experimented on. Thus the yields remained still higher under wide spacing of 12 sq. ft. per plant than under close or medium spacing. Thus closely spaced crop still continued to suffer from insufficiency of nitrogen even when manured with 50 lb. or 75 lb. nitrogen in the form of groundnut cake or sulphate of ammonia. But when 100 lb. nitrogen was applied, as in the case, Experiment II (1945-46), the yields under close, medium or wide spacing were nearly equal (Table VIII). This was due to a greater increase in yield under closer spacing and correspondingly lesser increase in yield under wider spacing in the presence of 100 lb. nitrogen. In Experiment IV this conclusion did not hold good where even in the presence of 100 lb. N the yields were significantly higher in the two wider spacings (12 sq. ft. and 16 sq. ft.) than under medium spacing (8 sq. ft. per plant). Thus there may be another factor that operated in the case of wider spacing. Observations on the crop indicated that the root growth appeared to be suppressed under close spacing even when nitrogen was applied while root growth was very extensive and vigorous in the case of widely spaced plants. That may be causing lesser reproductive growth with slightly lower yields when the crop was closely spaced and heavily manured.

The different length to breadth ratios under each spacing type kept as treatments in Experiments I and II did not produce any differences in yield. As, for instance, in the spacing of 12 sq. ft. per plant, whether the crop was spaced 4 ft. $\times$ 3 ft. or 6 ft $\times$ 2 ft., the yields came out to be the same. Thus six feet between rows and two feet between plants would be the most convenient spacing from the agricultural point of view.

Nitrogen was also found to influence the relative growth rate and relative leaf growth rate. Nitrogen-treated plants exhibited greater rate of growth than the control plants during the first two months of their development after which there was a greater decline in the manured plants than in the unmanured plants.

Application of nitrogen was also found to hasten maturity. This finding was in agreement with those of Collings [1926] and Buie [1928].

Nitrogen applications were found to decrease significantly the fruiting coefficient in this cotton, indicating that the added nitrogen was more utilized in increasing vegetative growth than in increasing reproductive growth. Hence the efficiency for seed cotton production per unit dry matter declined when nitrogen was added. The greater vegetative growth was in the form of a greater increase in the dry weight of the stems and branches than in the dry weight of the leaves.

The application of phosphorus in combination with nitrogen appeared to increase further the vegetative growth as well as the yield but this finding required further confirmation.

The chemical analysis of the leaves for other nutrients showed that the concentration of potash in the leaves increased as the spacing became wider, but that was not the case with phosphoric acid or lime. It was, therefore, possible that absorption of potash from the soil was also greater under wider spacing than under closer spacing but the application of potash did not produce any effect on either the vegetative or the reproductive growth.

Summary

Four factorial experiments were laid out to determine the effect of spacing, nitrogen, potash and phosphoric acid on the growth and yield of Surti cotton (*G. herbaceum* var. *acerifolium* (Guill. etc. Perr.) with a view to find out the causes of higher yields of seed cotton per acre under wider spacing than under closer spacing. The lower yields of seed cotton per acre under close spacing were caused by the suppression in the extension growth and the reproductive growth. Height, flower and boll production and yield were significantly less under close spacing than under wider spacings even though the total dry matter per unit area was higher in the former than in the latter.

The lesser reproductive growth was mainly caused by an insufficiency of nitrogen and partly by the less vigorous development of the root system when the crop was spaced very closely, viz., at 3 or 4 sq. ft. per plant.

Nitrogen concentrations of the leaves at the time of fruiting were found to be higher under wider spacing than under closer spacing both in the manured and unmanured conditions.

Close spacing and nitrogen application tended to hasten maturity while they both gave rise to lower fruiting coefficient.

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GROWTH STUDIES IN *SACCHARUM OFFICINARUM*
IV. TILLERING IN RELATION TO CANE WEIGHT

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(With two text-figures)

Barber [1919] exhaustively examined differences in the canes growing in the same clump by dissecting the clumps of various cane varieties. Indigenous groups of canes, namely, *Mungo*, *Saretha*, *Sannabile*, *Pansahi* and *Nargori*, unclassified cane varieties, *Saccharum spontaneums* and noble canes were dissected and formulae of tillering in each case were worked out to indicate the differences in shoots actually developed, dormant buds, dead buds and runners. He noticed that wild *Saccharums* 'head the list in the extension of their formulae'. The thick canes, in the character of their branching, show themselves furthest removed from the wild *Saccharums*. Then come in order the *Sunnabile* and *Nargori* groups which approach the thick canes, then *Saretha*, *Mungo* and *Panasahi*, which are nearer to the wild kinds. Besides, he studied the average length of basal part, with joints under one inch in length, average length of joints (above basal part) in the first 2 ft., average thickness of cane at 2 ft. from the base, rate of maturing of shoots of different orders, etc., to describe the distinguishing features of the various groups of canes.

Leake [1935] reviewing the work in Philippines drew attention to the fact that a large drop, amounting to 50 per cent in stool weight, in the number of canes per stool between the first and second year of seedlings was found to occur. Hill [1935] referred to the replies of a questionnaire issued by the International Sugar Cane Technologist Association and therefrom substantiated the observations recorded in Philippines, namely, mean stool weight and cane number both decrease by about half in the second year of the seedling over that of the first.

Turner [1935] studied the influence of manuring on germination and tillering. He observed that early tillers were increased by 40 per cent with ground lime stone, 70 per cent with ammonium sulphate and 10 per cent with sulphate of potash, the action of phosphate being neutral. With high nitrogen dose phosphate exerted a marked beneficial influence. Together nitrogen and potash or nitrogen and lime responded beneficially than the sum of their independent effects.

Panje [1943] studied the progress of tillering and mortality of shoots up to the harvest of the crop. He also observed the effect of irrigation and manuring on tiller production and survival of shoots. Millable length, girth of stalks, weight of cane and juice quality separately of mother shoots and tillers of the first order

were examined. He noticed that manuring increased tiller production and 'the quality of cane as measured by the average millable length, girth, weight per cane, sucrose content and purity of juice, was found to fall with successive later classes of shoots as was survival ratio'. He considered that both the size and quality of the harvest was improved by hastening early germination and early tillering of the crop.

The studies reported in this paper were conducted with the object of determining how far the weight of cane is influenced by the size of clump and whether total weight per clump decreased or increased with the increasing number of tillers per clump.

Material and methods

In a five acre field of sugar cane at Agricultural Sub-station, Karnal, which had a very uniform growth of the crop and had received the same cultural, manurial, and irrigation treatments, one thousand plants were labelled in the month of July. There were in all 110 rows of 660 feet length. Leaving aside five rows on either side, 100 rows were taken for this study. Ten plants in each of the rows were labelled at random by consulting 3 digit random numbers [Fisher and Yates, 1938]. In each of the labelled plants the number of shoots were noted. This period was selected to avoid as far as possible inclusion of shoots which ultimately do not develop into stalks. Panje [1943] had shown that between the period 10 July to 29 July the average number of shoots produced per interval were only 1·63 per cent of the total shoots produced per plant. Further he had observed that none of these shoots survived whether it was of the 'A' or 'B' order.

In the month of February each of the plants thus labelled was harvested and weighed. Care was taken to avoid recording of the weights of those plants which had either been spoiled by attack of rodents, jackals or were borer infested. Thus plants having all healthy shoots were selected for determining the relationship between the mean number of stalks and the weight of the clump.

Experimental data

(*a*) *Relationship between plant weight and number of tillers.* The total number of plants available for study were 608. In Table I are given the data for the series:

Table I

Number of plants with various tiller number—variety Co. 312

Particular	Tiller number											Total
	1	2	3	4	5	6	7	8	9	10	11	
No. of plants	89	119	114	84	83	42	28	21	15	6	7	608
Percentage of total number	14·6	19·6	18·7	13·8	13·7	6·9	4·6	3·5	2·5	1·0	1·1	100

It is evident that about 80 per cent of the plants had tiller number below five. But on the average for all the 608 plants mean number of tillers per plant worked out to 3·80 tillers. Panje had suggested that plants should have at least three shoots well established by end of April.

TABLE II

Weight per plant and number of tillers in variety Co. 312

Weight per plant lb.	Number of tillers											Total
	1	2	3	4	5	6	7	8	9	10	11	
0·50	17	1	..	1	..	..	..	..	..	..	..	19
1·0	30	11	1	..	..	..	..	..	..	..	..	42
1·5	17	21	1	..	..	..	..	..	..	..	..	39
2·0	15	16	9	5	2	..	..	..	..	..	..	47
2·5	10	14	11	..	1	..	..	..	..	..	..	36
3·0	..	23	15	6	1	..	..	..	..	..	..	45
3·5	..	19	13	6	1	..	..	..	..	..	..	39
4·0	..	4	9	4	3	1	..	..	1	..	..	22
4·5	..	9	13	10	4	..	..	..	..	..	..	36
5·0	..	1	22	15	12	2	..	..	..	..	..	52
5·5	..	..	16	12	6	1	1	..	..	..	..	36
6·0	..	..	1	10	2	..	..	..	..	..	..	13
6·5	..	..	2	8	8	2	..	..	..	..	..	20
7·0	..	..	..	2	10	2	1	..	..	..	..	15
7·5	..	..	..	4	13	4	..	..	..	..	..	21
8·0	..	..	1	1	7	4	2	..	..	..	..	15
8·5	..	..	..	..	8	7	2	3	..	..	..	20
9·0	..	..	..	..	..	6	1	1	..	..	..	8
9·5	..	..	..	..	5	6	4	3	..	..	..	18
10·0	..	..	..	..	..	1	2	1	..	..	..	4
10·5	..	..	..	..	..	2	5	1	..	..	..	8
11·0	..	..	..	..	..	2	2	3	..	..	..	7

TABLE II—*contd.*

Weight per plant and number of tillers in variety Co. 312

Weight per plant lb.	Number of tillers											Total
	1	2	3	4	5	6	7	8	9	10	11	
11·5	..	..	..	..	..	1	5	2	1	..	..	9
12·0	..	..	..	..	..	..	..	1	1	..	..	2
12·5	..	..	..	..	..	..	1	3	..	..	..	4
13·0	..	..	..	..	..	..	..	1	1	..	..	2
13·5	..	..	..	..	..	..	..	..	3	3	..	6
14·0	..	..	..	..	..	..	..	..	2	1	..	3
14·5	..	..	..	..	..	..	..	1	1	..	..	2
15·0	..	..	..	..	..	..	..	..	..	2	..	2
15·5	..	..	..	..	..	1	1	1	2	..	..	5
16·0	..	..	..	..	..	..	..	..	..	..	1	1
16·5	..	..	..	..	..	..	..	..	1	..	1	2
17·0	..	..	..	..	..	..	..	..	..	..	..	0
17·5	..	..	..	..	..	..	..	..	1	..	2	3
18·0	..	..	..	..	..	..	..	..	..	..	1	1
18·5	..	..	..	..	..	..	1	..	..	..	..	1
19·0	..	..	..	..	..	..	..	..	..	..	..	0
19·5	..	..	..	..	..	..	..	..	1	..	1	2
20·0	..	..	..	..	..	..	..	..	..	..	..	0
20·5	..	..	..	..	..	..	..	..	..	..	..	0
21·0	..	..	..	..	..	..	..	..	..	..	..	0
21·5	..	..	..	..	..	..	..	..	..	..	1	1
TOTAL	89	119	114	84	83	42	28	21	15	6	7	608

In Table II are summarised the results of the relationship between plant weight and the number of tillers per plant. From this a statement is presented in Table III giving tiller number per plant (x), total number of plants (n), weight of plants in lb. (w), mean weight per plant in lb. (y) and mean weight per tiller in lb. (t).

TABLE III

Relation between tiller number, mean weight per plant and mean weight per tiller

Tiller number per plant (x)	Total number of plants (n)	Weight of plants lb. (w)	Mean weight per plant lb. (y)	Mean weight per tiller lb. (t)
1	89	119·0	1·34	1·34
2	119	307·0	2·58	1·29
3	114	458·0	4·02	1·34
4	84	415·5	4·95	1·24
5	83	539·0	6·49	1·30
6	42	359·0	8·55	1·43
7	28	291·0	10·39	1·48
8	21	232·0	11·05	1·38
9	15	208·0	13·87	1·54
10	6	84·5	14·08	1·41
11	7	126·5	18·07	1·64

On plotting y against x it was observed that the points lay on a curve which was very nearly a straight line (Fig. 1). As is evident from Table III the frequencies (n) are widely different. Hence the straight forward method of fitting a straight line by the method of least squares was not applied. Instead, Fisher's method of fitting polynomial curves when frequencies are unequal was adopted [Fisher, 1941].

The equation to the straight line is:

$$y = -0{\cdot}5228 + 1{\cdot}4980\, x.$$

Table IV gives the test of goodness of fit.

TABLE IV

Testing goodness of fit of a straight line

Source of variation	DF	Sums of squares	Variance	Variance Ratio	
				Actual	Theoretical
Regression constants	1	7043·29127			
Deviations of means of arrays from regression line	9	108·38369	12·04263	5·23	2·44 at 1 per cent
Within arrays (Error)	597	1375·79173	2·30451		
TOTAL	607	8527·46669			

It is seen from Table IV that the variance due to deviation of means of arrays from regression line is significantly (one per cent) different from variance within arrays showing thereby that the straight line does not give a good fit to the data.

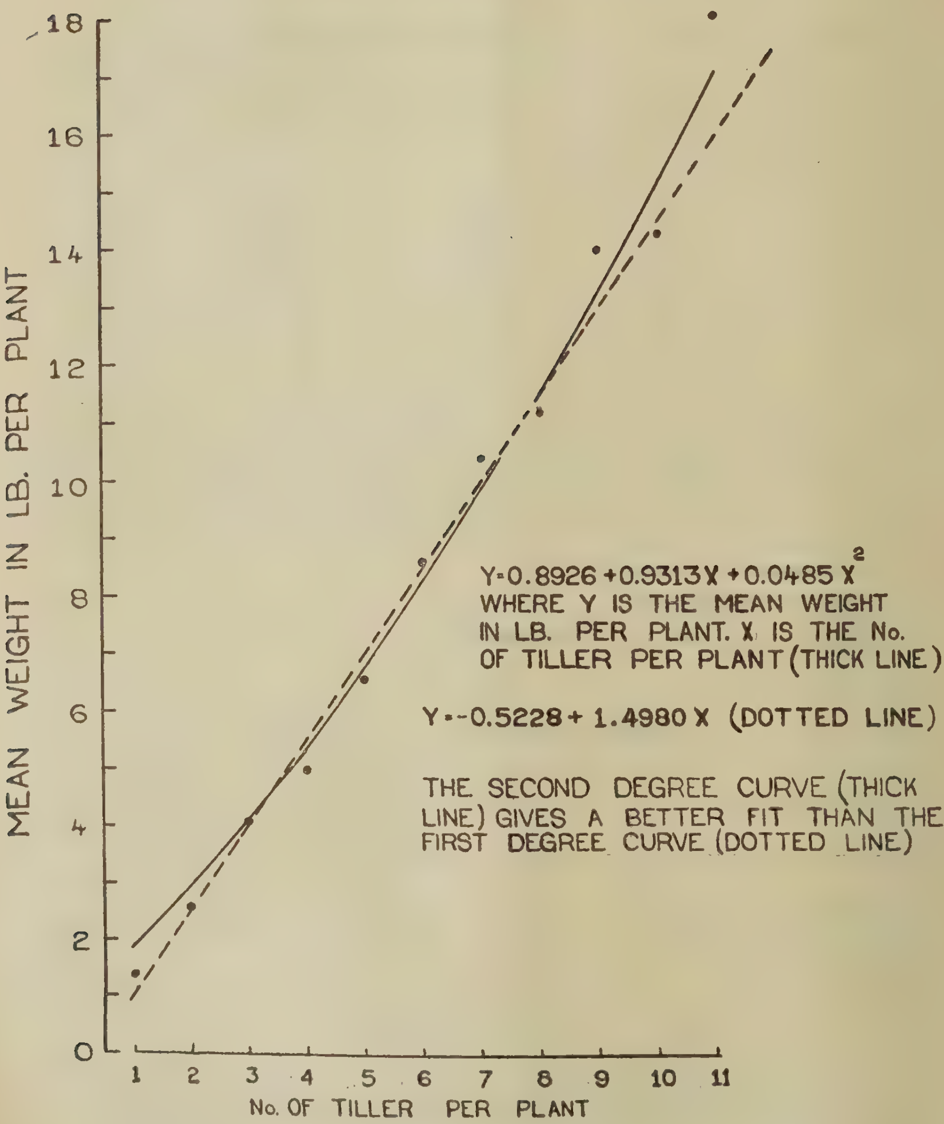

Fig. 1. Relationship between number of tillers per plant and mean weight per plant

Accordingly, curves of second and higher degrees were fitted. Table V gives the sums of squares, variance, etc. of deviations of means of arrays from regression line up to curves of the sixth degree.

TABLE V

Testing goodness of fit of curves of second and higher degrees

Degree of equation	DF	Sums of squares	Variance	Variance Ratio*			Remarks
				Actual	Theoretical at		
					5 per cent	1 per cent	
0	10	7151·67496	715·16750	..	..	..	
1	9	108·38282	12·04254	5·23	1·90	2·45	Sig. at 1 per cent
2	8	46·49418	5·81177	2·52	1·96	2·54	,, ,, 5 per cent
3	7	46·46783	6·63826	2·88	2·03	2·68	,, ,, 1 per cent
4	6	46·46773	7·74462	3·36	2·11	2·84	,, ,, 1 per cent
5	5	34·29928	6·85986	2·98	2·23	3·05	,, ,, 5 per cent
6	4	31·54949	7·88737	3·42	2·38	3·35	,, ,, 1 per cent

* The variance due to deviations of means of arrays from regression line is tested against 2·30451 variance within arrays.

It is seen from Table V that none of the curves gives a good fit to the data. This suggests that a very high degree or a complex curve would be required. We however, notice that, from the sums of squares i.e. 7151·67 between the arrays, only 108·38 with a variance of 12·04 is left over after fitting a first degree curve; 46·49 with a variance of 5·81 after fitting a second degree curve while the residual sums of squares for the curves of higher degree do not appreciably alter. In fact by testing the reduction in the deviation sums of squares due to each additional constant fitted, it can be shown that the fit does not improve significantly after the quadratic stage. Thus a second degree curve as representing approximately the relationship between plant weight and the number of tillers per plant may be regarded as fairly satisfactory. The second degree curve is represented by the equation:

$$y = 0{\cdot}8926 + 0{\cdot}9313\,x + 0{\cdot}04853\,x^2$$

Fig. 1 gives the first and second degree equations fitted to the data. This fit indicates that the weight of the plants increases more than is expected with the increase in the number of tillers and suggests study of the relationship between number of tillers and mean weight per tiller.

Relationship between mean weight per tiller and number of tillers per plant. The last column in Table III gives the mean weight (t) in lb. per tiller. It will be observed that upto five tiller numbers, the mean weight per plant does not vary much. The same appears to be true for figures of tiller numbers ranging from six to eleven. It was considered worthwhile to study whether the means of these two groups differ significantly.

Since the mean weights (t) per tiller were based upon widely different tiller numbers, comparisons were made between their weighted means and not their simple means. The sums of squares and other statistics were calculated by attaching appropriate weights to the mean weights (t). Let us denote the tiller number of group 1 to 5 by I and the tiller number of group 6 to 11 by II.

Also let t and n refer to the mean weight in lb. per tiller and the number of tiller classes respectively. Table VI gives the values of these :

TABLE VI

Mean weight per tiller, standard error, etc. of the two groups

	Group I	Group II	
n-1 (d.f.)	4	5	$\frac{s^2\ II}{s^2\ I}$ = 4·10 (not sig.)
t	1·29	1·47	
S^2	0·0013974	0·0057236	
SE	0·001468	0·001857	
D=tII—tI	0·18	S.E. D=0·002367 ; 't'=76 (highly significant)	

It will be seen from Table VI that the ratio of the two standard deviations is highly significant. Therefore the standard error of the difference between the two means was obtained by pooling the sums of squares. The results show that the mean weight per tiller of the second group is significantly greater than that of the first group.

It may be mentioned that the above result could be anticipated from the second degree equation of the previous section. This is seen by dividing the sum of the products of the expected values y with their corresponding plant numbers by the total number of tillers in the respective groups.

It is thus apparent that mean weight per tiller of group II is significantly greater than that for Group I.

In the previous section it had been shown that for all practical purposes it may be taken that the second degree equation represents the relationship between weight of plant and number of tillers per plant satisfactorily. Since the mean weight per

tiller is the weight per plant divided by the number of tillers, an equation to give a rough indication of the relationship would be of the form :

$$t=\frac{a}{x}+b+cx$$

where t is the mean weight in lb. per tiller, x the number of tillers per plant and a, b and c are the constants.

Accordingly, an equation of the above type was fitted by the Method of least squares. The equation thus obtained is as under :

$$t=\frac{0{\cdot}2142}{x}+1{\cdot}0907+0{\cdot}04159\,x$$

In Fig. (2) this equation fitted to the data by a line is shown. On both sides of the line the points are well distributed.

Significance of results

Vigour of cane plant is expressed in three ways, namely, the plant may develop a larger number of millable stalks, may have higher weight per stalk or may attain greater height of stalk. Since the crop was grown under uniform conditions of irrigation and manuring and the variety was the same it may be assumed that the relationships studied represent the characteristics of the variety. An analysis of data based on 608 plants has indicated that 80 per cent of the plants of variety Co. 312 have tiller numbers varying between 1 to 5. The mean weight per plant is 5·16 lb. For all practical purposes a satisfactory goodness of fit is given by the second degree curve. Obviously with the increase in tiller number there is no loss in weight per plant. On the contrary a slight appreciation in vigour of plant was indicated by a slightly steeper rise in the curve. Preliminary observations have indicated that in plants possessing larger number of tillers the immature shoots are fewer in number and the mortality of shoots is less. Panje [1943] has already stressed the need of early suckering.

A further critical examination of the data indicated a relationship between number of tillers and mean weight per tiller and is represented by the equation :

$$t=\frac{0{\cdot}2142}{x}+1{\cdot}0907+0{\cdot}04159\,x$$

where t is the mean weight in lb. per tiller and x the number of tillers per plant. The mean number of tillers per plant for all the data is 3·79. When the value of tiller number increases beyond the normal there is tendency for the curve to rise more steeply. Evidently no loss in vigour of shoots occurs by increased suckering and in plants having tillers more than 5 the weight per tiller is significantly higher than of plants possessing tillers fewer than five. Therefore, agronomic practices beneficial to increase suckering should be adopted to appreciably increase the tonnage of the crop.

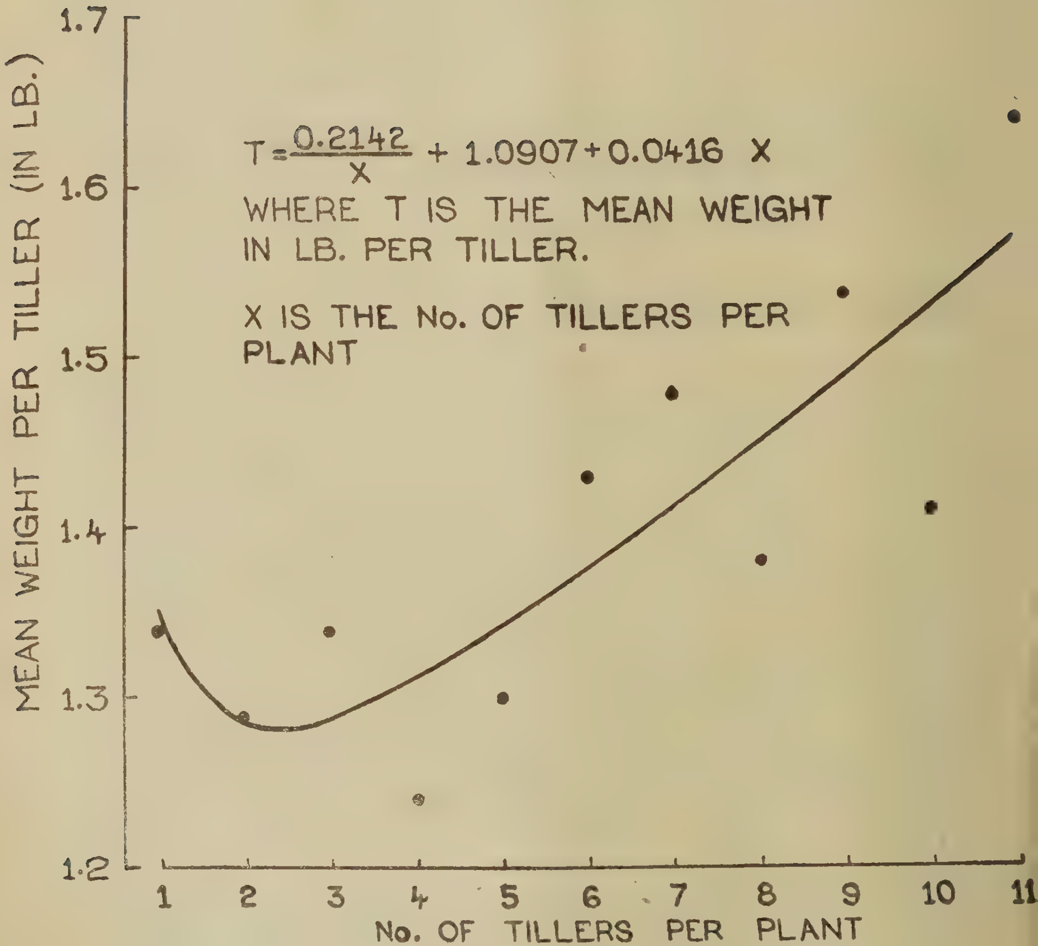

FIG. 2. Relationship between mean weight per tiller and number of tillers per plant

Summary

A critical study of the relationship between suckering and weight per plant and variations in mean weight per tiller has been reported which is based on the observations recorded on Co. 312. A second degree curve gave a more satisfactory goodness of fit to the data of the relationship between the number of tillers and mean weight of the plant and is expressible by the equation :

$$y=0{\cdot}8926+0{\cdot}9313x+0{\cdot}04853\ x^2$$

The fitted curve showed that relatively the weight per plant increased more than is justified by the increasing number of tillers. This suggested further analysis of the data. Accordingly the relationship between number of tillers and mean weight per tiller was studied since 80 per cent of plants had lesser number of tillers than 5, the difference between the mean weight per tiller for the two groups 1 to 5 and 6 to 11 was tested for significance. This difference was indicated significant at 1 per cent level of significance. The curve fitted to express the relationship was obtained as under :

$$t=\frac{0{\cdot}2142}{x}+1{\cdot}0907+0{\cdot}04159\ x \quad \text{where}$$

t being the mean weight per tiller against x number of tillers. The curve showed that when the value of tiller number exceeded the normal (3·79) there is tendency for the curve to rise more steeply. The analysis stresses the importance of increased tillering for appreciating the tonnage of the crop.

Acknowledgments

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MANURES AND MANURING OF THE MANGO AND THE ECONOMICS OF MANGO CULTURE

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Excepting a few non-economic varieties all the important mangoes flower only once a year. The seasonal growth cycle of mango under local conditions shows a brief rest period from middle of November, with the first advent of winter, to mid-December, when bud swelling commences. During this period most of the fruit bud differentiation takes place [Sen and Mallik, 1940]. Mango is generally a terminal bearer. The terminal blossom buds are first to start and, when they begin to break in early January, the leaf buds swell. The period of full bloom, though slightly varies in different varieties, may be taken to be from mid-February to mid-March and the period of first vegetative flush is also in the month of March. Fruit set is complete by early April and fruits mature from end of May to August, according to variety.

Generally three distinct flushes are found in mango, in March, June to July and October, though a few new shoots are always observed during any period of the year. The vegetative shoots grow rapidly for sometime and then stop elongation growth for a period after which they again continue. Quite often shoots are found to show growth in two or three sections within the period of first flush. When these sectional growths are separated by long intervals they appear as distinct flushes. The earlier shoots (February to March) get sufficient time to grow and cease elongation growth quite early in the season. They can properly mature before the fruit bud differentiation begins. But shoots of other two flushes grow slowly and also cease elongation growth late, thereby getting very little time to mature. Hence the chances of these shoots to bear is less. Thus under normal conditions only the earlier shoots flower in the following season.

It has been mentioned before that the period of the early flush and that of flowering coincides. As the physiological conditions for vegetative and reproductive growths are antagonistic shoot growth is inhibited when the majority of the existing shoots are in a condition to flower, or, there is little reproductive growth when the tree is producing vegetative growth. So actually the plant can reproduce in one season and vegetate in the next, depending on the nutritional condition of tree and soil. So it is seen that in the case of mango, like any other alternate bearing tree fruit, tree morphology contributes greatly to this phenomena of alternate bearing.

Butler [1917] explains such phenomena in apples and pears by the nature of their spur growth. The spurs generally flower in alternate years. Robert [1920] found that spur growth is related to annual bearing but Hooker [1925] observed

Already accepted by the Indian Science Congress of 1950, held at Poona and Summary published in the Proceedings.

that the tree behaved as a unit determining behaviour of the spurs. Chandler [1936] contended that a heavy crop inhibits fruit bud formation in the entire branch or tree bearing the crop, though the inhibiting influence is greatest on the branches bearing the fruit.

It seemed desirable to modify the cultural practices to induce the plant to bear annually. This is possible only when the mature terminal buds are not flowering all at a time but some remaining dormant during the ensuing flowering season and opening during the next ; or some of these buds producing vegetative growth. If 50 per cent of the mature buds remain dormant or open as vegetative shoots, and/or if the June to July shoots could be induced to mature during the current season, by proper manuring, a regular crop can be obtained every year.

It is evident that manuring on right lines, forms an essential annual operation, in successful orcharding. There is a lack of definite information on the manurial requirement of our fruit trees. With a view to get an insight into the mineral requirements of the mango, potculture experiments had been taken up at the station. The results (Sen, Roy and De, 1948] revealed that nitrogen controls growth and that the potash requirement of the mango is much higher than its phosphate requirement. Mango can not withstand potash deficiency. It has also been found that with the increase in the uptake of nitrogen there is a corresponding increase in the uptake of K and *vice-versa*. Also with greater intake of N more of P is utilized but the reverse does not hold good. There is an optimum effect of nitrogen, after which K deficiency symptoms are developed. The various deficiencies can be replenished before the critical stages are reached. To see if the results of these findings could be applied in practical mango culture, the following field manurial trials have been taken up at the Station.

Material, method and results

A manurial experiment on field scale basis was taken up in 1937 with a view to study the effect of N, P and K fertilizers. Stones from fruits of a single tree were taken and sown on 25-6-34. The seedlings were potted in September, 1934 and graded according to size. Inarching was done on 20-10-34 from a single Langra mango plant. The grafts were separated on 12-2-35 ; and were kept in pots till 10-3-37, when they were planted out in the previously prepared field. Before planting, the orchard soil upto 1 foot deep was analyzed. The analysis figures are detailed below :

Moisture	Loss on ignition	Total N2	Available	
			Potash	Phosphate
1.86 percent	1.92	0.042	0.0080	0.0085

The soil showed deficiency in nitrogen and organic matter. The experimental plants were planted in 1937 and the guard rows in 1938. They were allowed to establish themselves before any manuring was done. There were eight treatments, e.g., N, P, K, NP, NK, PK, NPK and control, in 6 replicated plots. Each plot

contained 2 experimental trees surrounded by 10 guard trees. The layout of the whole plantation was in square system, 24ft. × 24ft.

The manurial equivalents of N, P and K in the various treatments were 128·8 lb. per acre. The first application of manure was given in April, 1940. Sulphate of ammonia, superphosphate and sulphate of potash have been used. The manures are applied in a single dose every year, after the first shower, generally in the beginning of the fourth week of June, preceded by ploughing. For supplying humus to the soil the grasses and other vegetation growing in the orchard were ploughed in as a uniform practice.

It was decided that for the first 10 years equal doses of all the three nutritive elements would be supplied and their results compared to determine the preference of mango to any particular nutrient under local conditions.

Records on measurements of height, girth and spread of the individual plants have been kept from the first year of the plants. No significant difference in growth during the first three years (when the trees had no differential treatments) had been observed. Since the treatments were started the plants began to show difference which became pronounced from year to year.

TABLE I

Effect of different manurial treatments on growth of mango. Average of height and girth in centimetres of 12 trees in 6 replicated blocks per treatment taken in May every year before fertilizers are applied

Treatments	Heights					Girth				
	1945	1946	1947	1948	1949	1945	1946	1947	1948	1949
NPK	492	523	541	561	590	71	83	86	90	95
NP	472	502	525	532	559	67	77	80	83	87
NK	465	499	517	534	561	67	79	81	84	88
PK	453	465	470	476	485	67	75	75	76	78
N	473	481	495	516	542	67	76	78	82	85
P	437	450	456	462	472	66	71	72	73	75
K	460	470	480	501	511	60	72	73	75	77
Control	422	436	443	448	459	66	73	73	74	76

B.—*Increase in height and girth (in cm.) during 1947 to 48 and 1948 to 49*

Treatments	1947-48				1948-49			
	Height		Girth		Height		Girth	
	Mean increase	per cent of G.M.	Mean increase	per cent of G.M.	Mean increase	per cent of G.M.	Mean increase	per cent of G.M.
NPK	19·7	160·2	3·58	147·9	28·7	153	4·88	160
NK	7·4	60·2	2·91	120·2	27·1	145	3·73	123
NP	17·3	140·6	3·25	134·3	27·4	147	4·13	136
PK	6·4	52·0	1·42	58·7	9·2	49	1·85	61
N	20·5	166·7	4·08	168·6	26·1	140	3·33	109
P	6·2	50·4	1·4	57·8	9·7	52	2·14	70
K	15·6	126·8	1·79	7·40	10·4	56	2·18	72
Control	4·9	39·8	0·92	38·0	11·0	59	2·08	68
Mean	12·3	100·0	2·42	100·0	18·7	100	3·04	100
SE (*Mean* of 12)	·63	5·12	0·52	21·4	1·48	7·9	0·09	3·0
Significant difference	1·8	14·6	1·47	60·7	4·16	22·2	0·26	8·5
	2·3	18·7	1·95	80·6	5·51	29·5	0·34	11·1

TABLE II

Effect of different manurial treatments of flowering size of panicles and fruiting of mango. Total of 12 trees per treatment in 6 replicated plots

	NPK	NP	NK	PK	N	P	K	C	
1946	52	44	47	35	39	31	30	25	by eye estimation
1947	65	61	54	18	54	27	21	45	percent by counting
				Size of panicles in cm.					
1946	19	17	17	16	18	16	16	16	Length
	14	14	11	13	14	12	12	12	Breadth
1947	18	17	17	15	17	15	15	16	Length
	14	13	13	13	13	11	11	12	Breadth
1948	20	18	17	15	19	10	16	17	Length
	15	14	12	11	15	12	12	12	Breadth
				Number of harvested fruit per tree					
1946	290	150	90	70	114	71	23	36	
1947			Blossom spoiled						
1948	67	49	45	51	20	20	17	17	75 per cent of flowers were spoiled by hoppers

INTENSITY OF FLOWERING

Judged by eye estimation in 1946 by alocating numbers e.g. very poor flowering 1, poor 2, medium 3, good 4, and very good 5, and by actual counting and calculating the percentage of shoots in 1947.

The height and girth data collected upto date and compiled are presented in Table I. It may be seen that N has given significant effect in increasing growth ; P and K, either singly or in combination has shown little effect ; but N in combination with P and/or K has shown the best effect. The maximum effect has been found in plants under NPK. This is the trend of results from the very beginning. The intensity of flowering and fruiting of the trees and also the size of the panicles have been observed to vary directly as the growth (Table II). Fruits were normal in size, shape, taste and flavour.

Observation on the leaf colour which can roughly be taken as a measure of the general health of a plant, showed marked differences. The data were collected bi-monthly from August to June by eye estimation. The result of various years have been summarized in Table III. It is noticed that all the plants receiving nitrogen show a healthy green colour (figuratively nearer the maximum number 48 in the Table III). Very little difference has been found between the trees under treatments P, K and C.

TABLE III

The effect of different manurial treatments on leaf colour of mango trees ; 12 trees ; per treatment in 6 replicated plots

Year	NPK	NP	NK	PK	N	P	K	C
1945-46	47	34	39	30	36	23	24	22
1946-47	46	33	35	18	32	15	14	16
1947-48	45	43	42	24	24	44	19	19
1948-49	47	46	44	23	43	25	21	32

Eye—Estimation, taken bi-monthly.

(The figures represent mean values of the summation effects of bimonthly estimation on 12 trees per treatment in 6 replicated plots with 2 trees per plot, by assigning the following numbers 4 dark green, 3 green, 2 light green and 1 pale green)

In order to study the residual effect of different fertilizer treatments on N, P and K-contents of the soil of the experimental plots, soil samples were collected every year from 1946-50 at two depths, 0 in. to 6 in. and 6 in. to 12 in., in May, before the yearly application of fertilizers and were analysed. The results of analyses are given in Table IV. It may be seen, that whenever a certain element has been added, the soil shows a higher concentration of that element that in a plot not receiving it. Thus the NPK, NP, NK and N plots, receiving N show a higher nitrogen

TABLE IV

Result of soil analyses of the mango manurial trial block at Sabour and its figures indicate percentages on air oven dry basis; and its comparison with the fertility of Darbhanga soil (best mango growing tract in Bihar)

Treatments	Loss on ignition			Total nitrogen				Available phosphate				Total phos-phate	Available potash		pH 1948-49
(O in-6 in.)	46-47	47-48	48-49	45-46	46-47	47-48	48-49	45-46	46-47	47-48	48-49	48-49	45-46	46-47	(0″-12″)
NPK	3·1	3·5	3·65	·059	·053	·056	·050	·0089	·0182	·019	·018	0·152	·0069	·0220	7·1
NK	2·91	3·28	3·62	·056	·048	·052	·059	·0065	·0071	·0075	·0079	0·055	·0047	·024	6·5
NP	2·05	2·23	2·42	·058	·049	·051	·058	·0082	·0175	·0184	·019	·149	·0056	·015	6·8
N	3·2	3·65	3·68	·059	·053	·056	·062	·0064	·0067	·0051	·0055	·051	·0054	·014	5·6
PK	2·05	2·24	2·45	·052	·045	·049	·049	·0078	·0169	·0180	·0190	·05	·0068	·0250	6·9
P	2·12	2·45	2·50	·050	·049	·050	·050	·0077	·0168	·0185	·0185	·1091	·0050	·0076	6·7
K	2·21	2·54	2·49	·054	·048	·050	·049	·0061	·0073	·0082	·0085	·0955	·0073	·0280	7·4
C	2·44	2·80	2·65	·050	·049	·050	·062	·0062	·0088	·0085	·00880	·366	·0060	·0067	6·0
Laheriasarai	5·82	..	..	..	·085	..	..	..	·0075	..	..	..	..	·0081	..
NPK (6 in. 12 in.)	2·85	2·68	2·71	..	·033	·035	·042	..	·0085	·0095	·0098	·085	..	·023	..
NK ,,	2·42	2·38	2·45	..	·035	·035	·045	..	·0062	·0068	·0069	·032	..	·026	..
NP ,,	1·79	1·85	1·94	..	·030	·032	·039	..	·0091	·0123	·0125	·091	..	·0170	..
N ,,	1·75	2·14	2·65	..	·038	·039	·046	..	·0058	·0042	·0045	·034	..	·0160	..
PK ,,	1·58	1·75	1·70	..	·033	·031	·034	..	·075	·0092	·010	·145	..	·0250	..
P ,,	1·54	1·35	1·24	..	·041	·038	·036	..	·0089	·0099	0·110	·141	..	·0078	..
K ,,	1·68	1·78	1·81	..	·041	·038	·036	..	·0062	·0068	·0062	·035	..	·029	..
C ,,	1·84	1·78	1·85	..	·038	·037	·041	..	·0064	·0068	00·71	·049	..	·0065	..
(Laheriasarai 0 in.-12 in.)	3·54	..	..	..	·068	..	..	..	·0065	..	..	·0096	..	·0096	..
12 in.-24 in.	3·12	..	..	..	·057	..	..	..	·0051	..	..	..	..	·0095	..

content than the plots under C, P, K and PK which have never received any N. Similar are the cases for the other two elements too. It is also found that N-content of top 6 in. layer of soil remains almost constant without any significant increase. It decreases along with the depth. The percentage of loss on ignition, which roughly gives an idea about the organic content of the soil is found to be much less than those found in the soils collected from the best mango growing tracts of Bihar. This has also got a direct relation with the nitrogen content of the soil, varying along with it.

The phosphate and potash contents have increased upto a certain limit since 1946-47. Thenceforth the available phosphate content is nearly constant with insignificant increase. Only in N-plots the available phosphate content decreased enormously instead of remaining stationary. It may be seen in the Table IV that the *p*H of the soil of these N-plots is 5·6 which is definitely acidic. This is quite natural as these plots received only sulphate of ammonia consecutively for the last ten years. The soil being acidic most of the Fe and Al-contents go into solution and get depleted in the lower strata along with the leaching down of the phosphate content of the soil. This phosphate combines with the Fe and Al and get reprecipitated as insoluble phosphates.

There is a significant lowering of potash percentage in plots receiving nitrogen and/or phosphate. No such depression of N by addition of P has been noted. This lowering of potash in the plots not receiving it but receiving N and/or N and P indicates an increased utilization of K with the increase in N, which is in agreement with the conclusion drawn from the pot-culture study. On the other hand the relatively higher piling up of P in the soils receiving this element and a very little depression of it in plots not receiving it is suggestive of a relatively low phosphatic requirement of the mango. The phosphatic content of the plots under control and K treatments are greater than those under N and NK. This means that the addition of nitrogen in the soil increases the uptake of P. There is a regular uptake of P along with nitrogen absorption in N and NK plots, while relatively small intake of P has been found in C and K plots.

Thus it may be concluded that nitrogen controls the uptake of other elements and determines growth, and its effect is best manifested when it combines with K and P. Phosphate and potash either singly or in combination have little effect. The amounts of different elements required by a mature mango plant in a year have been found to be in the ratio of N : P : K :: 1·1 : 0·27 : 1·0, the amount of nitrogen being 1·67 lb. Flowering and fruiting have been found to be directly proportional to the growth of the tree.

Orchard soil analysis

Taking these into consideration for comparison and with a view to assess the potentiality of the soil for further development of fruit orchards, soil samples at three depths have been collected from different best mango orchards of the State and analysed. The results are presented in Table V. It may be seen that in all the tracts the top layer contains the maximum nitrogen percentage which gradually

TABLE V

Results of soil analysis of mango tracts of Bihar

Locality	Layers	Loss on ignition	Nitrogen	Available		N/P_2O_5
				Potash	Phosphate	
Hajipur (Muzaffarpur)	1	5·12	0·068	0·0078	0·0063	10·8
	2	4·91	0·049	0·0085	0·0043	11·4
	3	2·41	0·041	0·00090	0·0038	10·8
	4	1·85	0·039	0·014	0·0036	10·8
Laheriasarai (Darbhanga)	1	5·62	·086	·0081	·0075	11·4
	2	3·54	·068	·0096	·0065	10·4
	3	3·12	·057	·0095	·0061	9·3
	4	2·84	·043	·00114	·0059	7·3
Maner (Patna)	1	4·1	·065	·0089	·0089	7·3
	2	3·02	·046	·012	·0076	6·1
	3	2·54	·035	·012	·0054	6·5
	4	2·04	·035	·012	·0052	6·7
Bhagalpur	1	3·84	·058	·0069	·0095	6·1
	2	2·35	·042	·0072	·0075	5·6
	3	2·36	·027	·0085	·0068	4·0
	4	1·84	·026	·0085	·0065	4·0
Japla	1	4·23	·06	·0098	·0059	10·2
	2	3·95	·054	·0095	·0051	10·6
	3	3·43	·048	·0088	·0048	10·0

TABLE V—*contd.*

Results of soil analysis of mango tracts of Bihar

Locality	Layers	Loss on ignition	Nitrogen	Available Potash	Available Phosphate	N/P_2O_5
Chanki (Palamou)	1	4·1	·068	·0089	·0069	9·8
	2	4·3	·065	·0074	·0058	11·2
	3	4·4	·053	·0069	·0054	9·8
Jamui	1	4·9	·068	·012	·0039	17·4
	2	4·75	·061	·013	·003	20·3
	3	4·7	·055	·014	·0028	19·6
Bikramganj	1	3·25	·059	·035	·019	3·1
	2	3·3	·045	·029	·016	2·8
	3	3·45	·039	·024	·013	3·0
Kanke (Ranchi)	1	2·84	·046	·02	·0019	2·4
	2	3·25	·041	·024	·0024	1·7
	3	3·41	·035	·026	·0028	1·3

1=first layer from 0-6 in., 2=Second layer from 6 in.-12 in., 3=12 in.-24 in. 4=24 in.-36 in.

diminishes with increasing depth. Among the places nitrogen content of top layer soil of Laheriasarai (Darbhanga) is the maximum and that of Ranchi is the minimum ; the difference is significant. At lower layers the difference decreases. The available phosphate content of the soils also is maximum at top layers and decreases gradually with increase in depth, except in Ranchi where it increases. Ranchi has got a lateritic acid soil and so the phosphates are fixed at a lower strata just as was found in N-plots of the manurial experiments at Sabour. The available K-content, however, increases slowly with depth.

The organic and N-content of the orchard soil of Darbhanga is much higher than those of the NPK plot at Sabour even after 10 years of constant nitrogen supply. Darbhanga is one of the most extensive mango growing area of Bihar and the soil of these parts have, besides a high N and organic contents, a very large percentage of Ca (upto 35 per cent in some parts). Mango grows very well here and the soil condition of Darbhanga may be taken as standard. It is interesting to note that the ratio between N and P is roughly constant at any particular place irrespective of the depth but this ratio varies from place to place. The best mango growing

tracts of Bihar, *viz.*, Darbhanga, Bhagalpur and Patna have got this ratio varying from 6 to 10 which might be an index for better mango culture.

Pilot experiments

A few pilot experiments have further been carried out here at this station in order to determine the best organic or inorganic manures and also the best time for their application. The experiments had been carried out with different sets of mango as enumerated briefly below :

Experiment I

To determine the best time of application of manure to overcome biennial bearing tendency. Nitrogenous manures in the form of sulphate of ammonia and farm yard manure have been applied on the same set of trees (mango var. *Saker-thina*) every year immediately after harvest. This induced vegetative flush in July to August which matured during the same season and produced increased flowering in the following season. It will be evident from the data (Table VI) that the flowering level of the trees has been increased both in the 'on' and 'off' years but still the alternate bearing rythm is persisting. The two unmanured trees showed acute alternate bearing habit.

Experiment II

To find out the most effective manures and the best time for applying them, three experiments have been conducted. (*a*) This experiment has been carried out since 1945-46 on 10 year old Langra mango growing in one plot. There are six treatments with four replications in each. One line of plants is under a separate treatment. All the trees were in the same bearing condition in 1945, when the experiment was started. The amount of nitrogen per plant per year as F.Y.M. and/or ammonium sulphate was kept the same, viz., 1 lb. The treatments are—(i) control, (ii) ammonium sulphate in June, (iii) F.Y.M. in June, (iv) F.Y.M. plus ammonium Sulphate in June, (v) F.Y.M. in October, (vi) ammonium sulphate in June and F.Y.M. in October. The plots containing the plants have two ploughings a year.

Table VI

Effect of nitrogen manuring in 'on' year on flowerings in the following years

Variety : Saker-china Tree number	7 years in 1942 Behaviour in 1942	Treatment	Total number of panicles per year									
			1942	1943	1944	1945	1946	1947	1948	1949	1950*	
1	Heavy bearing	A	346	168	1307	272	752	542	1080	474	B	306
2	do.	B	292	2	845	89	107	314	455	789	A	800
3	Light bearing	B	74	200	25	55	90	525	564	499	B	419

Treatments : A—Manured during the last week of June every year with $1\frac{1}{2}$ md. of F.Y.M. and 2 lb. of sulphate of ammonium

*As the tree no. 2 flowered heavily manuring was done to this tree after 1949 harvest

The effect of the treatments on flowering of each of the plants were observed. The results are presented in Table VII. It will be evident from the table that ammonium sulphate in June followed by F.Y.M. in October has given the best result, specially in the 'off' year.

(*b*) In order to see the effect of manuring in the 'on' year only, an experiment was started in 1945 with 23 years old Langra mangoes showing acute alternate bearing habit. All the plants were growing in one plot under similar cultural conditions. Number of treatments were three with five trees in each treatment in each of the three varieties of mango, viz., Langra, Bombai and Fazli. The five plants per treatment in each of the varieties were in one plot of 0·11 acre and were separated by one guard row, while the treated plants of each variety were separated by three guard rows. The treatments consisted of (i) Control, (ii) F.Y.M. in October, and (iii) Ammonium sulphate in June in 'on' years only. All the plants received ploughings every year. Manures were applied at the rate of 100 md. per acre of F.Y.M. and 5 lb. of ammonium sulphate per tree. During 1946 and 1947 the blossom was spoiled due to untimely rain and hoppers and so both the years were regarded as 'off' year. Treatment 3 was not given. Still the plants under treatments 2 and 3 produced more flower than control. The year 1948 was an 'on' year as there was a fair crop though the bloom was not very heavy. Treatment 3 was given in June, after harvest. During the next bloom all the plants of the experiment, however, flowered so heavily that no significant difference could be noticed between the control and the manured plants.

(*c*) In this experiment which was started in 1945 with 10 year old Langra mango nitrogenous manure was supplied singly and in combination with phosphatic manure in June and/or October. All the plants were receiving similar cultural care before the differential treatments of this experiment were given, they were in the same stage of bearing. The treatments were (i) control, (ii) N alone in June, (iii) N and P in June, (iv) N alone in October and (v) N and P in October. The orchard received 3 ploughings during the year. F.Y.M. at the rate of $2\frac{1}{2}$ md. per tree and bonemeal $2\frac{1}{2}$ seers per tree was used for supplying N and P respectively. The effect of different treatments as observed on flowering is presented in Table VIII. It may be seen that N alone in June or October appears to give the best flowering though during 1947-48 it was observed that N when supplemented by P in October had the best effect.

On comparing the result of the above experiments it may be seen that N in the form of ammonium sulphate is most effective in increasing the flowering of the treated plants and that the best time for the application is the month of June, Nitrogen in the form of F.Y.M. applied in October is also beneficial but its effect is manifested not in the season following but one year after. F.Y.M. is slow in action but it does give an increased flowering over the control. Potash should be applied along with N as the intake of one is dependsd on the intake of the other. Phosphate is advantageously used by the plants if a slow acting manure e.g., bonemeal is given along with F.Y.M. in October.

TABLE VII

Manurial trials in mango variety Langra in 'D' area

Treatments	Extent of flowering					
	1946-47		1947-48		1948-49	
	Mean values	Per cent of G. M.	Mean values	Per cent of G. M.	Mean values	Per cent of G. M.
Control	69·9	94	11·8	38·3	95·5	71
Ammonium/Sulphate in June	98·4	128	32·0	105·2	160·8	120
F. Y. M. in June	81·8	110	17·7	58·2	191·8	143
F. Y. M. and Ammonium/ Sulphate in June	65·9	89	39·7	130·6	187·5	154
F. Y. M. in October	57·8	78	22·5	74·0	44·5	33
F. Y. M. in October and Ammonium/Sulphate in June	74·6	101	68·7	193·1	122·0	91
General mean	74·1	100	30·4	100	133·7	100
S. E.	10·8	14·6	1·19	3·9	28·1	21·0
Critical difference	30·9	41·7	4·84	15·9	84·3	63

TABLE VIII

Manurial trials in mango variety Langra in planting block

Treatments	Extent of flowering					
	1946-47		1947-48		1948-49	
	Mean values	Per cent of G. M.	Mean values	Per cent of G. M.	Mean values	Per cent of G. M.
Control	20·8	47	12·0	59·4	23·0	68
F. Y. M. in June	36·2	61	15·2	75·2	50·2	148
F. Y. M. in October	77·0	129	18·5	91·6	61·8	182
F. Y. M. and bonemeal in June	70·6	118	13·8	68·3	25·5	75
F. Y. M. and bonemeal in October	86·6	145	41·7	206·4	9·5	28
General mean	59·7	100	20·2	100	34	100
S. E.	6·78	11·4	4·91	34·3	9·29	27
Critical difference	25·6	42·9	16·5	81·7	27	79

The above findings have been applied in practical commercial mango culture and the economics have been worked out. The results are given in appendices. It may be seen that if proper cultural care is taken, mango can be made to bear annually and its culture made more profitable. Manuring in June with nitrogen has given an extra profit of upto Rs. 250 per acre over the profit from the control block at a demonstration plot at Muzaffarpur, and manuring with easily available N, in June, after harvest, in 'on' year has fetched an extra income of Rs. 100 per acre at a demonstration plot at Bhagalpur.

On the basis of these experiments the following manurial schedule has been drawn up to tide over the difficulties caused by non-bearing and over bearing of mango plants. Manures to be used in the pit at the time of transplanting the grafts from pots :—F.Y.M.—1 md. ; castor cake 2½ sr. and bonemeal 2 sr. Then from the end of the first year in field till tenth year the annual increase over the doses of the first application should be @ 10 sr. of F.Y.M. upto 80 sr. ; ½ sr. of bonemeal upto 5 sr. ; wood ash from 5 sr. (at the end of first year of field life) increased @ 1 sr. upto 10 sr. For mature trees of 10 years and above, the annual doses should be 2 md. of F.Y.M., 2 sr. of castor cake, 5 sr. of bonemeal, 1 sr. of ammonium sulphate and 15 sr. of wood ash. Cake could be substituted for F.Y.M. (one for ten) ; superphosphate for bonemeal (equal quantity) ; potash sulphate for ash (one for ten). Fertilizers must always be used along with organic manures.

It must also be remembered that ammonium sulphate (for immediate supply of N) in June followed by F.Y.M. (slow acting) in October give the best result. Phosphates should be used along with F.Y.M. in October. This helps the development of fruits. F.Y.M. is slow in action and it gives out a slow but steady supply of N, which is advantageously used by the shoots in forming fruit bud or producing vegetative flush. Potassic manure is to be used with every manuring either in June or in October. Hence it is better to divide the recommended yearly dose into two corresponding parts, one containing ammonium sulphate plus half the potassic manure to be used in June and the other consisting of F.Y.M. and phosphate along with the remaining potash manure in October. In the 'on' years, however, the dose of ammonium sulphate should be doubled for forcing July to August vegetative growth and helping them to mature before the rest period in November to December so that they might blossom during the next season of 'off' year. This extra dose should be applied after a fortnight of the first application. The orchards should be ploughed during the time of manuring and an extra ploughing should be given during the winter rains in January to February to conserve the soil moisture for the succeeding dry period from March to May.

Conclusion

It has been found from field trials that N has given significant effect in increasing growth ; P and K, either singly or in combination has shown little effect. N in combination with P and/or K have given the best results ; maximum effect however has been achieved under NPK. The amount of the different elements required by an adult mango plant per year are in the ratio of N : P : K : : 1·1 : 0·27 : 1·0,

the amount of nitrogen being 1·67 lb. Flowering and fruiting of the plants have been found to be directly proportional to their growths. These confirm the findings of the mango pot-culture experiments.

N in the form of ammonium sulphate is most effective in increasing flowering and the best time for its application is in the month of June. N in the form of F.Y.M. applied in October is also beneficial but as it is slow acting its effect is manifested later than those obtained by using ammonium sulphate still F.Y.M. has shown increased flowering over the control. Intake of K is most vigorous in presence of N and so it is applied along with N. P is advantageously used by the plant if a slow acting manure e.g., bonemeal is given along with October ploughing. So it may be concluded that ammonium sulphate in June followed by F.Y.M. in October is best for better reproduction in mango. Potassic manure is used with every manuring, either in June or in October. Hence it is better to divide the recommended dose of N, P and K manures into two parts, one containing ammonium sulphate and half of K manure for June application and the other consisting of F.Y.M., and phosphate along with the remaining half of K for October. In 'on' years, the dose of ammonium sulphate should be doubled to force July to August vegetative shoots which mature and produce flower during the succeeding 'off' year.

Under the present price condition extra profit upto Rs. 250 per acre, has been obtained from mango orchard by manuring according to the above recommendations.

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Appendix A

Balance sheet of the cultural trials on mango during 1946-47. Orchard at the Fruit Research Station, Sabour. Trees were in the 'off' year in 1947

Control		Treated	
Northern plot of 1·5 acres with 60 plants, 20 of each variety of Bombai, Langra and Fazli, all 23 years old		Southern plot of 1·5 acres with 60 plants, 20 of each variety of Bombai, Langra and Fazli, all 23 years old	
Expenditure	Income	Expenditure	Income
Towards cost of ploughing,—three times in 1946-47, employing 6 ploughs at a time @Rs. 2 per plough (Rs. 2 × 6 × 3)....Rs. 36	From sale proceeds of 932 fruits in 1947 @Rs. 12 per cent....Rs. 112	Towards cost of ploughing,—three times in 1946-47, employing 6 ploughs at a time @Rs. 2 per plough (Rs. 2 × 6 × 3)....Rs. 36 Towards cost of manure at 10 cart loads per acre 15 cart loads @Rs. 4 per cart........Rs. 60 Towards cost of applying manure round the trees once along with June ploughing @as. 2 per tree..................Rs. 7-8 Towards cost of irrigation, three times during April and May, 1947 with mote @Rs. 20 per time..................Rs. 60	From sale proceeds of 2,704 fruits in 1947 @Rs. 12 per 100....Rs. 324
Total Rs. 36	Rs. 112	Rs. 163-8	Rs. 324-8

	Rs.
Net profit from the plot	76
Net profit per acre	50
Net profit from the plot	161
Net profit per acre	110

Or an extra profit of Rs. 60 per acre over the control was obtained.

Appendix B

Balance sheet of the cultural trials on mango

Effect of ploughing ; manuring and pruning in 'on' year of 1947 in inducing flowering and fruiting in 'off' year of 1948

Orchard at Devari in Darbhanga district

Control 2 acre plot		Experimental 2 acre plot	
Expenditure	Income	Expenditure	Income
Rs.	Rs.	Rs.	Rs.
No operation	From sale proceeds of 800 fruits @Rs. 7 per 100..........56	Towards cost of manure....50 Towards cost of ploughing....40 Towards cost of pruning....18 Total cost..............108	From sale proceeds of 7,200 fruits @Rs. 7 per 100..........504
	Net profit............56	Net profit..........396	

A net profit of Rs. 170 per acre was obtained.

APPENDIX C

Balance sheet of the cultural trials on mango at Muzaffarpur during 1948-49
Trees were in the 'on' year in 1949

Treated orchard (5 acres)	Rs.	A.	P.	Untreated orchard (5 acres)	Rs.	A.	P.
Total income :							
From sale proceeds of 33,750 fruits @Rs. 10 per 100 .	3,375	0	0	From sale proceeds of 20,250 fruits @Rs. 10 per 100 . . .	2,050	0	0
Less expenditure :							
Towards cost of cultivation 30 pairs of bullocks +Rs. 2-8-0 per pair	75	0	0	Towards cost of cultivation (same as in the treated orchard) .	75	0	0
Towards cost of manuring 25 md. of castor cake @Rs. 7 per md.	175	0	0				
Towards cost of labour for spreading the manure . . .	7	8	0				
Total expenditure . . .	257	8	0	Total expenditure . . .	75	0	0
Net income . . .	3,117	8	0	Net income . . .	1,950	0	0
Or Rs. 624 per acre				Or Rs. 390 per acre			

So the extra profit accrued from the treated orchard was Rs. 234 per acre over the profit from the check plot.

APPENDIX D

Balance sheet of the cultural trials on mango at Bhagalpur during 1948-49. Trees were in the 'off' year in 1949. The entire 2 acre orchard was ploughed twice in June and in September, 1948, and meth *fodder was grown. Half of the orchard was manured with F. Y. M. and Ammonium Sulphate in June after harvest.*

Manured half	Rs.	A.	P.	Unmanured half	Rs.	A.	P.
Total income :							
From sale proceeds of 75 baskets of mango	750	0	0	From sale proceeds of 60 baskets of mango	600	0	0
From sale proceeds of *meth* .	75	0	0	From sale proceeds of *meth* .	20	0	0
	825	0	0		620	0	0
Less expenditure :							
Towards cost of ploughing . .	20	0	0	Towards cost of ploughing . .	20	0	0
Towards cost of manure . .	104	0	0				
Total expenditure . . .	124	0	0	Total expenditure . . .	20	0	0
Net income . . .	701 per acre	0	0	Net income . . .	600 per acre		

So an extra profit of Rs. 101 per acre was obtained over the profit accrued from the untreated half.

AVAILABILITY OF NITROGEN IN SOILS AND MANURES

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(With one text-figure)

THE importance of nitrogen in the make up of soil fertility has been well known. Lawes, Gilbert and Warington [1883] have shown that major portion of soil nitrogen is inert and that in the soil, the availability of nitrogen was dependent upon the additional supply of easily nitrifiable nitrogen. The available forms of nitrogen has been considered to bear a relation to the total quantity of combined nitrogen. But Gainy [1930] modified this view by studying this relationship more closely. He showed that available nitrogen was not related to the total but to that part of the total which could undergo bacterial decomposition.

Tiurin and Kononova [1934] determined the nitrogen requirements of the soil by hydrolysing the soil organic matter with 0·05 N sulphuric acid and estimating the nitrogen in the filtrate. Tiurin [1935] suggested the determination of nitrogen and oxidisable carbon obtained by the hydrolysis of soil with 80 per cent sulphuric acid (Waksman's proximate method of analysis) as the principal biological processes in the soil are those of hydrolysis and oxidation. Hydrolysis with 80 per cent sulphuric acid has been used by several workers for characterising the soil organic matter [Nikolov and Milyakova, 1939; Tatankov, 1938]. In this paper the results of an investigation to find the nature of relationship between 80 per cent sulphuric hydrolysable nitrogen and the nitrifiable nitrogen are reported.

Experimental

Procedure for the determination of nitrogen hydrolysable by 80 per cent sulphuric acid in manures and soils

Tiurin's procedure of hydrolysis consisted in treating the soil with 80 per cent sulphuric acid in the cold for about two hours, then diluting with water and boiling. The readily hydrolysable compounds are thereby brought into solution. This procedure was standardised as follows. Different manures were treated with 80 per cent sulphuric acid in the cold and nitrogen was estimated in the extracts at intervals of 4, 8, 24, and 48 hours. The results are given in Table I.

The results in Table I show that the hydrolysis of nitrogenous compounds increases with the time and tends to reach a maximum after 24 hours. As such the values after keeping the acid in contact with the material for 48 hours has been taken as the maximum hydrolysable fraction for comparative purposes.

TABLE I

Amount of nitrogen extracted by 80 per cent sulphuric acid with time

Manures	4 hours		8 hours		24 hours		48 hours		Total N
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	
1. Compost	0·24	19·0	0·32	25·4	0·46	36·5	0·52	41·2	1·26
2. F. Y. M.	0·30	17·7	0·35	21·0	0·52	31·1	0·56	33·5	1·67
3. Green manure	1·11	34·6	1·46	45·6	1·73	53·9	1·68	52·3	3·21
4. Mustard cake	5·69	88·9	5·90	93·5	6·16	96·3	6·14	95·4	6·40
5. Act. Sludge	..	..	..	..	1·34	67·3	1·34	67·3	2·10

a : per cent N extracted
b : per cent N extracted of the total N

The method adopted finally was as follows: 1 to 2 gm. of finely powdered material (in the case of soils 25 gm.) were treated with 25 c. c. (in the case of soils with 50 c.c.) of 80 per cent sulphuric acid for about 48 hours shaking thoroughly at periodic intervals and the centrifuged supernatant liquid was filtered through glass wool to remove the particles floating at the surface of the extract. A suitable aliquot of the filtrate was taken and the total nitrogen was estimated (by the method given in the Methods of analyses of Association of Official Agricultural Chemists, Washington, 5th edition page 4).

The carbon extracted by 80 per cent sulphuric acid was also estimated by the wet digestion method by oxidation with chromic acid in an apparatus which is similar to the one used by Subramanyan, *et al.*, [1934]. The following alterations were made in their apparatus so as to insure greater accuracy: (*a*) two towers containing potassium iodide and iodine were included for the absorption of acid fumes (*b*) aspiration was introduced for regulating the whole working of the apparatus (*c*) the flow of carbon dioxide in the absorption system was forced against falling alkali drops effecting a thorough and complete absorption of carbon dioxide.

Organic manures and their hydrolysable fractions

The total carbon, 80 per cent sulphuric acid extractable carbon, and the total nitrogen of the organic manures studied are given below in the Table II.

For purposes of comparison the 80 per cent sulphuric hydrolysable fractions of soil are also included in the table.

It is seen from Table II that in the case of mustard cake 96 per cent of the total nitrogen is extractable by 80 per cent sulphuric acid while F. Y. M. ranks last among the manures with only 33·5 per cent sulphuric hydrolysable nitrogen. Activated sludge and green manure cowpeas rank second and third respectively with 64·7 and 52·3 respectively. In the case of the soil only 25 per cent of the nitrogen being

TABLE II

Analysis of manures for hydrolysable fractions

Manures	Total N per cent	Total C per cent	Sulphuric C per cent	Sulphuric N per cent	C/N	Sulphuric C/sulphuric N	Percentage of sulphuric N of the total	Percentage of sulphuric C of total C
1. Compost	1·26	12·75	3·11	0·52	10·1	6·0	41·2	24·0
2. F. Y. M.	1·67	18·4	4·2	0·52	11·0	7·9	33·5	23·0
3. G. M. cowpeas	3·21	26·3	9·62	1·68	8·2	5·7	52·3	36·0
4. Mustard cake	6·40	41·2	22·32	6·16	6·4	2·8	96·0	54·0
5. Act. sludge	2·10	12·37	5·08	1·36	5·9	3·7	64·7	41·0
6. Soil	0·044	0·31	0·043	0·011	7·1	4·0	25·0	14·0

extractable by 80 per cent sulphuric acid. In general this ranking generally appears to follow their availability to crops.

According to Springer [1943] the easily oxidisable carbon represented by the amount extracted by 80 per cent sulphuric acid is available for biological purposes. From this point of view also the order is the same as that of sulphuric hydrolysable nitrogen, the maximum occurring in the case of mustard cake (54 per cent) and minimum (23 per cent) in the case of F. Y. M. amongst the manures studied. In the case of soil only 14 per cent of the total carbon was extractable by 80 per cent sulphuric acid.

The C/N ratio was generally narrow except in F. Y. M. and compost and decreased in the following order: F. Y. M., Compost, green manure cowpeas, mustard cake and activated sludge. Both the total C/N ratio and sulphuric carbon/sulphuric nitrogen tallied except in the case of last two in which the order was reversed.

Nitrifiability of organic manures

In order to study the extent to which this hydrolysable nitrogen is convertable into nitrate and the factors affecting their conversion, laboratory experiments have been conducted to determine their nitrifiability. For this purpose, soil samples brought from a field experiment were given the following treatments (same as those given in the field trials) at the rate 30 mgm. of nitrogen per 100 gm. of soil: 1. No manure 2. F.Y.M. 3. Activated sludge 4. Mustard Cake 5. Compost 6. GM. Cowpeas 7. F. Y. M. P_2O_5 +K_2O 8. Activated sludge+P_2O_5+K_2O 9. Mustard Cake+P_2O_5+K_2O 10. Compost+Ammonium sulphate N+P_2O_5 11. (F. Y. M. ammonium sulphate) N+P_2O_5 12. Ammonium sulphate+P_2O_5+K_2O. Inorganic nitrogen, phosphate and potash were also included in the treatments at the rate of 30 mgm. per 100 gm. of soil to study their effect on nitrification.

The soils were incubated at optimum moisture and temperature which were previously determined to be 12 per cent (half the saturation capacity and 32°C respectively). The nitrate was determined periodically at fortnight intervals in 1 : 5 water extracts by phenol-di-sulphonic acid method by comparing the yellow colour in Lovibond Tintometer. The amounts of nitrate formed under each treatment are given in Table III.

TABLE III

Nitrification of different manures and fertilisers

(Nitrate in mgm. per 100 gm. of soil).

Treatment	Period in days						
	0	15	30	45	60	75	90
1. No manure	0·53	3·1	3·3	3·0	3·0	3·2	3·45
2. F. Y. M.	1·30	4·8	5·4	4·3	5·1	5·1	4·8
3. Activated sludge	0·50	10·1	11·6	12·7	13·5	13·2	13·7
4. Mustard cake	Traces	15·0	15·6	13·8	15·0	14·9	14·7
5. Compost	3·45	7·4	7·8	7·4	7·2	7·4	7·8
6. G. M. Cowpeas	0·50	6·5	8·1	11·0	12·5	11·7	12·4
7. F. Y. M.+P_2O_5+K_2O	1·2	3·0	4·2	3·6	3·8	3·9	4·05
8. Act. Sludge+P_2O_5+K_2O	Traces	11·4	9·2	10·8	11·3	11·3	13·5
9. Cake+P_2O_5+K_2O	Traces	14·4	15·6	14·4	13·2	14·4	16·8
10. Compost+Ammonium sulphate+P_2O_5	1·8	16·5	17·4	13·2	12·8	14·4	17·7
11. F. Y. M.+Ammonium sulphate+P_2O_5	0·69	16·5	15·9	15·6	14·4	14·4	15·9
12. Ammonium sulphate+N+P_2O_5+K_2O	0·6	21·3	28·4	27·0	24·0	24·0	23·5

In the case of organic manures F. Y. M., Act. sludge, mustard cake, compost and green manure, the maximum amount of nitrate was formed in about a month's time (*vide* Table III) in most of the above treatments except in the cases of activated sludge and green manure which reached maximum a little later. Soon after the maximum was reached there appeared to be slight fluctuation round the maximum value. The following is the descending order of nitrification of the organic manures :—Mustard cake, activated sludge, green manure, compost, and F.Y.M.

The combined effect of additions of phosphate and potash at the rate 30 mgm. of P_2O_5 and K_2O each respectively per 100 gm. of soil on the nitrification of F. Y. M., activated sludge, and mustard cake in the Delhi soil appeared to depress the course of nitrification. It is likely that phosphate may not have any influence on nitrification and the above depression may be attributable to the additions of potash. The available K_2O in Delhi soil is fairly high and additions of any extra potassium salt might have become toxic to nitrifying bacteria. The toxic effect of potash is also generally reflected in the depressed yields of crops obtained in Delhi soil by the additions of potassium to the soil. Further there appears to be negative correlation

between the amounts of potash present in the organic manures corresponding to 30 mgm. of total N and the amount nitrified as shown in the following Table IV.

TABLE IV

Relation between potash content and nitrifiability of manures

Manure	K_2O corresponding to 30 mgm. of N	Nitrate formed (excess over control)
F. Y. M.	32·6	2·0
Compost	29·3	4·4
Activated sludge	10·3	10·3
Mustard cake	6·7	12·2

The effect of addition of inorganic nitrogen and phosphate along with organic matter (phosphate at 30 mgm. P_2O_5 and nitrogen at 30 mgm. made up equally of inorganic and organic forms) increased the amount of nitrate formed but the increase was proportional to the amount of inorganic nitrogen added.

Relationship between sulphuric hydrolysable nitrogen and nitrifiable nitrogen of organic manures

From the nutrition point of view, it is only in the form of nitrate that nitrogen is absorbed from most of the ordinary soils [Russel, 1937]. Hence all methods to test the availability of nitrogen must ultimately bear a relation to the nitrifiability of manures. It is therefore necessary to examine the extent to which the 80 per cent sulphuric hydrolysable nitrogen is actually nitrifiable.

In Table V are given the total sulphuric nitrogen, (soil+manure) the amounts of nitrate formed, the per cent of sulphuric nitrogen nitrified in the organic manures.

TABLE V

Percentage of sulphuric nitrogen nitrified

Treatment	Total sulphuric N (soil+manure) mgm. per 100 gm.	Nitrate formed mgm. per 100 gm. of soil	Percentage of nitrifiable N of the total sulphuric nitrogen
1. No manure	9·85	3·5	35·5
2. F. Y. M.	20·70	5·4	26·1
3. Compost	23·40	7·8	33·4
4. Green manure cowpeas	28·0	12·5	44·6
5. Activated sludge	29·0	13·7	47·2
6. Mustard cake	39·0	15·6	40·0

Although the total nitrogen added through manures is at the rate of 30 mgm. per 100 gm. of soil the total sulphuric nitrogen given in the column 1 of Table V varies from 9·8 mgm. in the case of no manure to 39 mgm. in the case of mustard cake. With respect to these organic manures there appears to be good correlation between sulphuric nitrogen and the amount of nitrate formed. In order to find out the exact relationship between sulphuric nitrogen and nitrate formed it is necessary to consider the carbon oxidised during the process.

The following table gives the data for the initial hydrolysable nitrogen carbon actually oxidised during incubation, their ratio and the nitrate formed :

TABLE VI

Relationship between sulphuric N, carbon oxidised and the nitrate formed

Treatment	(*a*) Sulphuric N (in soil + manure) in mgm. per 100 gm. soil	(*b*) carbon oxidised in mgm. per 100 gm. of soil	Ratio of (*a*) to (*b*) multiplied by 100	Nitrate formed in mgm. per 100 gm. soil
		(Organics)		
F. Y. M.	20·7	261	7·1	5·4
Compost	23·4	168	13·9	7·8
Act. Sludge	29·0	152	19·1	13·7
G. M. Cowpeas	28·0	142	19·7	12·5
Mustard cake	39·0	161	23·5	15·6
		(Organics+inorganics)		
F. Y. M.+P_2O_5+K_2O	20·3	211	9·6	4·1
Activated Sludge+P_2O_5+K_2O	30·6	167	18·3	13·5
Cake+P_2O_5+K_2O	40·6	141	28·8	16·8
Compost+Ammonium sulphate P_2O_5	31·2	126	24·8	17·7
F. Y. M.+Ammonium sulphate P_2O_5	30·0	116	29·9	16·5
		(Inorganics)		
Ammonium sulphate +P_2O_5+K_2O	40·0	71	56·3	28·4

It is seen from Table VI that there is a direct relationship between nitrate formed and the ratio of sulphuric nitrogen to carbon oxidised. This straight line relationship is also clear from the Fig. 1. Thus the formation of nitrate is directly proportional to sulphuric nitrogen and inversely to the oxidisable carbon in the medium.

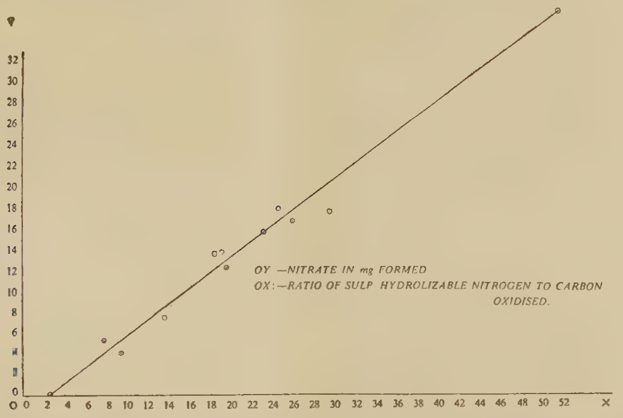

FIG. 1. Relationship between nitrate formed and the ratio of sulphuric hydrolysable nitrogen to carbon oxidised

In the case of complete artificials where nitrogen is added in the form of ammonium sulphate, the easily oxidisable carbon is minimum (71 mgm. per 100 gm. of soil) and hence maximum nitrogen has been nitrified (28·4 mgm. out of 30 mgm. of nitrogen added). On the other hand, in the case of F. Y. M., the oxidisable carbon was 261 mgm. and hence only 5·4 mgm. of nitrogen was nitrified.

SUMMARY

In view of the need to have a rapid chemical method for testing the availability of nitrogen in manures and soils instead of the usual time consuming nitrification tests, the nitrifiable nitrogen was compared with 80 per cent sulphuric hydrolysable nitrogen. Although the order of nitrifiability is the same as the sulphuric hydrolysable nitrogen, the data shows that the latter is a little higher than what can be nitrified. Further there was a direct relationship between the nitrate formed and the ratio of sulphuric hydrolysable nitrogen and carbon oxidised during incubation.

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LEY FARMING EXPERIMENT*

I. EFFECT OF DIFFERENT FERTILIZERS ON THE YIELD AND QUALITY OF RHODES GRASS (*CHLORIS GAYANA*) AND LUCERNE (*MEDICAGO SATIVA*) MIXTURES

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THE fodder problem in India is undoubtedly as acute as the problem of maintaining the soil fertility. The system of ley farming advocated by Sir R. G. Stapledon and which has created so much lively interest in the grass minded countries of the West, is a system which needs to be seriously considered under Indian conditions for solving both these pressing problems. The ley consists of two complementary parts viz. grasses and legumes. The former has the valuable quality of improving the soil structure and when grown in association with legumes, the latter enriches the nitrogen content of the soil by the activity of their nodule organisms. The association also affords a highly nutritious fodder for the cattle.

Since the system involves almost a reorientation of the present agricultural pattern through the adoption of grass-legume mixture as a crop in the rotation, much experimental data is necessary before it is possible to advocate the system under Indian conditions. With these considerations in view an exploratory experiment on ley farming was started at the Indian Agricultural Research Institute in 1945. The experiment consisted of two parts. In the first part the effect of different manurial treatments on the quality and quantity of Rhodes grass-lucerne ley under irrigated conditions was to be studied for three years. In the second part the residual effect of this three years' differently manured ley on the succeeding unmanured maize and wheat crops was to be studied. The results of the first year 1945-46 have been reported by Parr and Sen [1947]. The first part was completed in 1948 and the consolidated data from 1945-48 is reported in the present paper. The second part is under study.

Seed mixture

The ley is primarily meant for the welfare of the cattle ; therefore, the components in the seed mixture must be specially chosen. An ideal seed mixture would be one which gives a highly palatable balanced fodder of grass and legume throughout the duration of the ley and is easily removable after its completion. Rhodes grass which has been found very satisfactory under Delhi conditions and lucerne a perennial legume, were used in mixture. Subsequent observations, however, showed that this simple mixture does not afford a balanced forage. Rhodes grass contributes the

*Paper read before the Indian Science Congress, 1950.

bulk during *kharif* while lucerne forms the major proportion in the *rabi* season. The mixture thus needs to be expanded by addition of a suitable *kharif* legume to balance with Rhodes grass and a *rabi* grass to balance with lucerne.

Treatment and layout

The economics of ley farming depends upon the maximum fodder production which in its turn is intimately connected with the effectiveness of the ley on the soil. The performance of the mixture was, therefore, studied under ten manurial treatments with six replications. The fertilizers included N, P and K in the form of sulphate of ammonia, superphosphate, and sulphate of potash, respectively, alone and in combination ; P in the form of bonemeal alone and in combination with N and K ; NP in the form of ammonium phosphate and a control no manure plot.

Establishment of the ley

Mixture of Rhodes grass and lucerne was broadcast on 28 February, 1945 at the rates of 22 lb. (with husk) and 36 lb. per acre respectively. In the compounding of seed mixture normal seed rate of Rhodes grass was used while more than the normal seed rate of lucerne was thought necessary as the crop was to be sown out of season. The stand of Rhodes grass was uneven and, therefore, additional seed of the grass at the rate of 10 lb. per acre was broadcast on 19 May, 1945. As some of the lucerne stand was smothered by the Rhodes grass, which became apparent after the second cutting, the plots were reseeded on 3 January, 1946 with a mixture of lucerne and berseem at the rate of 12 lb. and 20 lb. respectively. Berseem was included in order to compensate for the loss in yield which would have occurred owing to uneven stand of lucerne. Berseem contributed to the fodder only in the third cutting. No further seeding was done in the subsequent years. The plots were intercultured and irrigated after each cutting. Fertilizers were applied each year.

Yield of green fodder

During the duration of the ley 10 cuttings were taken at an approximate interval of three months. The results are tabulated in Table I.

The highest yield was obtained under a combination of superphosphate and ammonium sulphate (NP) and with further addition of potash sulphate (NPK). This was followed by the combination of phosphate and nitrogenous ingredients in the form of ammonium phosphate. Superphosphate alone (P) and the combination of N and K with the phosphatic ingredient as derived from bonemeal (NPK) came next. Ammonium sulphate alone or in combination with P_2O_5 derived from bonemeal did not show marked response over the control, while bonemeal and potash individually have shown depressing effect.

Effect of treatments on the lucerne stand

Since much emphasis is to be given to the legume component of the ley, lucerne stand was examined in each plot before the 9th cutting and the plots were arbitrarily

classified under 4 categories, viz. 1. good, 2. medium, 3. poor and 4. very poor, or negligible, of lucerne. When compared with the treatments interesting correlations were obtained as given in the Table II.

Table I

Fodder yield in md. per acre per treatment in different cuttings

Number of Cutting	Treatments										
	No manure	Ammonium sulphate 80 lb.	Superphosphate 80 lb. P_2O_5	Potash sulphate 80 lb. K_2O	Bonemeal 80 lb. P_2O_5	N+P 80+80 lb.	N+P+K 80+80 +80 lb.	N. 80 +bonemeal 80 lb. P_2O_5	N+K 80+80 +bonemeal 80 lb. P_2O_5	Ammonium phosphate 80 lb. N	C. D. at 5 per cent level
*1. August '45	241·3	384·4	203·1	188·3	190·8	363·7	304·7	289·5	307·9	385·4	72·7
*2. November '45	84·7	123·4	72·6	81·9	76·5	107·6	119·7	93·7	110·5	145·8	33·1
3. March '46	53·9	49·2	142·1	53·3	36·1	121·0	142·6	57·2	54·6	100·6	24·8
4. June '46	32·2	36·8	70·6	32·6	25·2	78·4	96·1	36·1	39·4	56·7	18·1
*5. December '46	105·5	118·2	144·5	95·9	100·0	209·3	192·0	159·6	163·7	187·3	43·0
6. June '47	44·1	43·1	94·1	43·4	43·3	76·3	87·1	49·7	46·3	62·2	24·3
*7. August '47	62·0	72·8	125·3	77·4	54·4	130·3	113·2	72·0	69·2	111·8	32·5
*8. December '47	65·9	104·7	94·2	68·6	58·1	134·0	157·5	117·6	117·6	148·5	[illegible]4·0
9. March '48	60·8	36·4	100·5	35·6	46·5	73·4	77·3	40·3	47·4	74·9	26·9
10. June '48	17·5	18·4	46·3	8·6	13·4	34·5	32·5	12·5	16·6	25·7	14 4
Total for 10 cuttings.	767·9	987·4	1093·3	685·6	644·3	1328·5	1322·7	928·2	973·2	1298·9	64·0

* These cuttings mainly consisted of Rhodes grass, the remaining predominantly of lucerne.

Table II

Correlation of the lucerne stand with treatments

Treatments	Number of plots under each category			
	Good	Medium	Poor	Very poor
A. No manure	1	2	2	1
B. Ammonium sulphate 80 lb. N.	..	1	3	2
C. Superphosphate 80 lb. P_2O_5	4	1	1	..
D. Potash sulphate 80 lb. K_2O	1	1	2	2
E. Bonemeal burnt 80 lb. P_2O_5	..	3	1	2
F. Ammonium sulphate 80 lb. N+Superphosphate 80 lb. P_2O_5	3	1	2	..
G. Ammonium sulphate 80 lb. N+Superphosphate 80 lb. P_2O_5+potash sulphate 80 lb. K_2O	1	5	..	..
H. Ammonium sulphate 80 lb. N+bonemeal 80 lb. P_2O_5	..	1	5	..
I. Ammonium sulphate 80 lb. N+bonemeal 80 lb. P_2O_5+Potash sulphate 80 lb. P_2O_5	..	1	5	..
J. Ammonium phosphate 80 lb. N	1	4	..	1

When the number of plots under different treatments falling under the first two and last two classes are taken into consideration it will be observed that wherever the phosphatic element as derived from superphosphate or ammonium phosphate has been included in the treatment as in C, F, G and J, more than half the plots viz. 5, 4, 6 and 5 respectively out of 6 replications, fall under the first two categories ; while more than half the plots under treatments B, D, H, I, viz. 5, 4, 5 and 5 respectively fall under the third and the fourth classes, the plots under treatment E being equally divided.

Nutritive value of the fodder

The crop was sampled before the second cutting where Rhodes grass predominated and again before the third cutting. No further samples were analysed. The data is presented in Table III.

TABLE III

Nitrogen content, P_2O_5 and CaO content in crop samples on dry basis

	A	B	C	D	E	F	G	H	I	J	
Nitrogen per cent	0·83	0·735	0·786	0·743	0·885	0·660	0·692	0·669	0·698	0·799	In composite crop samples taken before 2nd cutting (November 1945).
P_2O_5 per cent	0·89	0·299	0·385	0·268	0·290	0·325	0·348	0·255	0·263	0·401	
CaO per cent	0·725	0·730	0·839	0·725	0·722	0·636	0·677	0·784	0·678	0·929	
Nitrogen per cent	2·64	2·65	3·67	3·19	3·18	2·73	3·52	2·89	2·63	2·69	In composite crop samples taken before 3rd cutting (March 1946).
P_2O_5 per cent	0·75	0·67	0·93	0·82	0·61	0·43	0·56	0·42	0·36	0·44	
CaO per cent	2·95	3·54	3·15	3·20	2·86	2·85	3·08	3·35	2·88	2·68	

The conclusions reached by Parr and Sen were as follows :

In the samples where Rhodes grass predominated, increase in the CaO and P_2O_5 content was obtained under the application of ammonium phosphate and superphosphate. No variation in the nitrogen was obtained under any treatment. In the samples where lucerne formed the bulk N, P_2O_5 and CaO contents were appreciably increased by the application of superphosphate.

Economics of manuring

The economics of manuring in this experiment is presented in Table IV.

The highest net profits were obtained under ammonium phosphate treatment. Superphosphate alone or in combination with ammonium sulphate gave very high profits. Bonemeal alone or in combination with ammonium sulphate has given very high net loss and so also the potassium sulphate treatment.

Table IV

Economics of manuring

Treatment	Total quantity of fertilizer added during 1945-48					Cost of fertilizer	Fodder yield	Extra yield	Value of extra yield	Net Profit in Rs.
	Ammonium sulp. lb.	Superphosphate lb.	Bonemeal lb.	Potash sulp. lb.	Ammonium phos. lb.	Rs. As. P.	Md.	Md.	Rs. As.	
No manure	..	..	..	..	..	..	767·9	..	..	..
Ammonium sulphate lb.	1200	..	..	..	..	176 12 6	987·4	219·5	165 0	11·76
Superphosphate 80 lb. P_2O_5	..	888	..	..	..	135 2 3	1093·3	325·4	243 12	108·6
Potash sulphate 80 lb. K_2O	..	..	..	480	..	62 11 0	685·6	—82·3	—61 8	—124·18
Bonemeal 80 lb. P_2O_5	..	..	1033	..	..	85 14 0	644·3	—123·6	—93 0	—178·87
Ammonium sulphate 80 lb. N+superphosphate 80 lb. P_2O_5	1200	888	..	..	..	311 14 9	1328·5	560·6	420 0	108·5
Ammonium sulphate + superphosphate + Potash sulphate 80+80+80 lb.	1200	888	..	480	..	374 9 9	1322·7	554·8	416 4	41·62
Ammonium sulphate 80 lb. N+bonemeal 80 lb. P_2O_5	1200	..	1033	..	..	262 10 6	928·2	160·3	120 0	—142·62
Ammonium sulphate bonemeal+ potash sulphate 80+80+80 lb.	1200	..	1033	480	..	325 5 6	973·2	205·3	153 12	—142·6
Ammonium phosphate 80 lb. N	..	..	..	..	1500	241 10 9	1298·9	531·0	398 4	156·56

N. B.—The cost of fodder calculated at 12 annas a maund.

Discussion

From the yield table it will be seen that the application of phosphatic fertilizers in the form of superphosphate alone or in combination with ammonium sulphate, or in the form of ammonium phosphate, to the ley, significantly increased the yields of fodder in all the cuttings ; the lime and phosphoric acid contents were also appreciably increased. The stand of legume component under these treatments was maintained throughout the duration of the ley (Table II).

The importance of phosphatic manures in improving the quality and quantity of the ley as also in maintaining the stand of the legume component, has been stressed by several workers. Russell [1937], Richardson [1924], Oswald [1936], Jansson Theoder [1932], Noll *et al.* [1944], and Odland [1948]. From economic point of view the application of ammonium phosphate and combination of ammonium sulphate and superphosphate or superphosphate alone was highly profitable.

From the results of the first two cuttings, it will be seen that the application of ammonium sulphate alone showed a very marked response and gave the second best

yield. These two cuttings predominated in Rhodes grass. The importance of nitrogenous manures in the initial establishment of the ley has been demonstrated by William Davis [1949] and Irwin [1945]. The continued application of ammonium sulphate, however, failed to show the initial response and the yields were, almost, at par with no manure plots, irrespective of whether the major bulk was contributed by the grass or the legume. Further, the legume stand was also very poor at the end of the ley period under this treatment. This suppression of leguminous plants due to nitrogenous manuring has been shown by Russell, Blackman [1938], Oswald, Nicholaison *et al* [1938], Eheart *et al* [1941] and Robinson *et al* [1947].

Potassium sulphate and bonemeal have individually shown a definite negative response the latter showing more depressing effect. In combination with N and K, however, bonemeal showed a better response thus pointing out the efficiency of the combination of nitrogenous and phosphatic manures over individual ingredients.

The mixture of Rhodes grass and lucerne in the light of the present results is likely to prove suitable for incorporation in the farm rotation as neither component reappeared after the ley was ploughed up in 1948 for the study of the second aspect of the experiment, viz. the effect of manured ley on the yields of subsequent unmanured maize and wheat crops. The effect of the ley was not visible in the first year after the ley was ploughed and the yields in general were low. The beneficial influence, however, commenced in the second year and very good yields of 17 md. per acre of maize grain and 15·5 md. per acre of wheat were obtained without manuring. The yields are not stabilized so far and the experiment is being continued. The results will be reported in due course.

Summary

An exploratory experiment on ' ley farming ' with the object of studying (I) the effect of different fertilizers on the yield and quality of Rhodes-grass-lucerne ley and (II) the effect of 3 years manured ley on soil fertility as judged by yields of unmanured maize and wheat crops, was started in 1945. The results of the ley period (Part I) for 1945-48 have been discussed.

The application of phosphate fertilizers in the form of superphosphate alone and in combination with ammonium sulphate, or in the form of ammouium phosphate to the ley, significantly increased the yields and improved the quality.

The stand of lucerne was favoured by the application of phosphatic fertilizers.

Nitrogen favoured the initial establishment of the ley. Continued application decreased the yields and diminished the legume stand.

Application of ammonium phosphate or combination of ammonium sulphate and superphosphate was economical.

Acknowledgments

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DETERMINATION OF OIL IN OIL SEEDS (RAPID METHOD)

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DETERMINATION of oil content in oil seeds is of paramount importance to the plant breeders who are interested in improving the oilseed crops. The conventional extraction method* being expensive and time consuming and as it usually requires large samples for the purpose, various rapid methods ** have been developed. However, due to certain inherent disadvantages they have not come very much in use, particular mention may be made of the method of Ludwig and Lompe [Loc. cit.] which though rapid is handicapped by the fact that it fails when applied to the examination of seeds grown under different soil and climatic condition which bring about a slight variation in their constituents.

Method

The method involves the following five steps-sampling, grinding, extraction with benzene, filtration and evaporation. The material from 0·4 to 0·5 gm. is sampled out and transferred to a mortar. Approximately 2 gm. of glass powder† and about 2 gm. of anhydrous sodium sulphate are added to the mortar and then the material is reduced to fine powder. The powdered material is carefully transferred to a 50 c.c. Erlenmeyer flask and the pestle and mortar is carefully washed 3 to 4 times with 2 to 3 c.c. of benzene every time, the washing being transferred to the flask. The mixture is refluxed for about 30 seconds on a hot plate or sand bath and is then filtered through a sintered funnel into a 25 c.c. graduated flask. The flask is carefully washed several times with hot benzene till the washings amount to 24 c.c. approximately. The measuring flask is removed and the volume is made up to the mark. An aliquote is pipetted out in a small tared dish and evaporated to constant weight in a vacuum oven at 100°C. Generally 30 minutes are sufficient to drive away all the benzene. The percentage oil is calculated from the following formula.

$$\text{Oil percentage} = \frac{W1}{W2} \cdot \frac{25}{V} \cdot 100$$

where W1 is the weight of the oil, W2 the weight of the substance taken and V is the volume pipetted for evaporation.

*Reference No. 6.

**References 1 to 5.

†(Method for the preparation of glass powder) Broken pyrex glass apparatuses were reduced to powder in an iron pestle and mortar. The powder was washed thoroughly with tap water to remove the dusts and dirts and then boiled with concentrated hydrochloric acid in a fume chamber, till the acid evaporated. This was done twice and then washed with tap water till free from acid. Finally it was washed with distilled water and dried on a sand bath.

RESULTS

The values of the oil content obtained by the method were in very close agreement with those obtained by petroleum ether (40-60° C.) extraction in the Soxhlet extractor. In the conventional method petroleum ether was always used as the sulphuric ether extraction gave higher values of oil content due to the solubility of non-fatty matters in the latter. The extraction was carried out for about 16 hours using about 3 gm. of the sample.

The oil content of seeds on moisture free basis as determined by the rapid method was in agreement when carried out with air dried and oven dried seeds up to 6·5 per cent moisture. Seeds with higher moisture content were not tried.

TABLE I

Results of extraction with petroleum ether (40 to 60° C.) and sulphuric ether

Serial number	Extraction with sulphuric ether	Extraction with petroleum ether	Deviation
1	40·87	38·90	
2	40·70	39·10	
Average	40·79	38·50	+2·29

TABLE II

Oil contents of the seeds with different amount of samples

Serial number	Weight of the sample	Rapid method	Soxhlet method	Deviation
		Percentage of oil content	Percentage of oil content	
1	0·2504	45·00	45·80	—0·80
2	0·3000	45·10	45·80	—0·70
3	0·3500	45·40	45·80	—0·40
4	0·4000	45·25	45·80	—0·55
5	0·4520	45·30	45·80	—0·50
6	0·5000	45·50	45·80	—0·30
7	0·7500	45·60	45·80	—0·20
8	1·0012	45·80	45·80	—0·00

TABLE III

Oil content of linseed strains

Serial number	Variety	Oil content		Deviation
		Percentage of rapid method	Percentage of Soxhlet method	
1	RR 67	47·30	47·30	0·00
2	RR 39	42·80	43·20	—0·40
3	RR 45	43·50	44·00	—0·50
4	RR 82	38·50	38·20	+0·30
5	RR 62	44·50	45·10	—0·60
6	RR 10	43·90	44·60	—0·70
7	RR 236	44·60	44·70	—0·10
8	NR 12	41·60	41·70	—0·10

TABLE IV

Oil content of Brassica *seeds*

Serial number	Variety	Oil content		Deviation
		Rapid method	Soxhlet method	
1	*Brassica campestris toria* T22	45·70	45·40	+0·30
2	*Brassica nigra* T267	39·70	39·20	+0·50
3	*Brassica juncia* Rai 215	41·20	40·96	+0·24
4	*Brassica cempestris* T 85	42·20	41·93	+0·27
5	*Toria* T 5	41·50	42·00	—0·50
6	*Toria* D 1	31·10	31·70	—0·60

Table V

Oil content of sesame seeds

Serial number	Variety	Oil content		Deviation
		Rapid method	Soxhlet method	
1	S1	45·60	45·80	—0·20
2	S4	48·80	49·10	—0·30
3	S6	49·80	49·80	0·00
4	S9	49·60	50·20	—0·60
5	Sesamum orientale NP 6	49·30	50·00	—0·70

Table VI

Oil content of Sunflower seeds

Serial number	Variety	Oil content		Deviation
		Rapid method	Soxhlet method	
1	EC 813 Coimbatore	26·18	26·33	—0·15
2	EC 814 Delhi	27·30	27·51	—0·21
3	EC 812 Pusa	33·30	33·27	+0·03
4	EC 813 Pusa	31·06	31·32	—0·26
5	EC 814 Pusa	30·08	29·94	+0·14
6	EC 885 Pusa	27·72	28·00	—0·28
7	EC 813 Delhi	37·44	37·46	—0·02
8	EC 814 Coimbatore	29·11	29·27	—0·16

TABLE VII

Oil content of oil cakes

Serial number	Variety	Oil content		Deviation
		Rapid method	Soxhlet method	
1	Linseed cake	10·90	10·70	+0·20
2	Groundnut cake	6·56	6·58	—0·02
3	Groundnut cake (Karnal)	7·10	7·40	—0·30

TABLE VIII

Oil content of seeds with different percentage of moisture

Serial number	Variety	Moisture	Oil content			Deviation
			Air dry	Oven dry calculated	Oven dry found	
1	RR 197	5·63	41·50	43·70	44·10	—0·40
2	RR 260	5·60	46·10	48·70	49·20	—0·50
3	Sesamum Orientale 1	6·10	45·60	48·30	47·90	+0·40
4	Sesamum Orientale 3	6·30	53·50	56·90	56·60	+0·30

It can be seen that the values of oil content obtained by the rapid method are not significantly different from those obtained by the Soxhlet method. The deviation between the two methods is not more than 0·70.

The error due to sampling and analytical procedure was also not significant.

The present method was developed with a primary object of determining the oil contents of large varieties of rust resistant linseed, being bred in the Division of Botany of the Indian Agricultural Research Institute. More than 350 strains of linseed from three year's (1948-50) crops have been analysed. This method has further successfully been applied to other small seeds and oil cakes and was found suitable for Sunflower seeds as well, though it was slightly cumbersome due to hard hulls of the seeds.

The method is expedient and economical and requires simple equipments and chemicals which are available in most of the laboratories. Vacuum drying is recommended when oil content of a drying oil seed is to be determined due to the ease of

oxidation of the oil. It is possible for a trained worker to analyse 8 to 10 samples of seeds in duplicate, in a working day of eight hours, with the help of this method. The method can utilize as low as 0·25 gm. of the sample, but generally 0·5 gm. of the sample is recommended.

Summary

An expedient and economical method for the determination of oil in small seeds and oil cakes has been developed.

For all practical purposes and particularly from the breeding point of view, there is no difference in the result obtained by rapid method and the conventional one.

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THE ROLE OF EARTHWORMS IN SOIL FERTILITY

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(Received for publication on 7 May 1951)

THE pioneer morphological observations of the habits and activities of earthworms underneath the soil surface were recorded in the last decade of the 19th century by Charles Darwin in his book entitled '*Earthworms and the formation of vegetable moulds*'. In this book Darwin has given a full and detailed description of the type of food taken or eaten by the earthworms, the type of soil and climate in which they flourish and the manner in which they bore their passages and tunnels under the soil surface, etc. Since then several workers, e.g. Hensen, Muller, Wollney, Stocki, Blank and Giesche in Germany; Russel and Salisbury in England; Anderson, Murinor, Lunt and Jackobson, Hopp and Slatter in the U. S. A. and Puh in China have studied this problem of the role of earthworms in soil fertility by adopting laboratory methods of physical and chemical analysis of soils and earthworms' excreta and by pot-culture experiments. As a result of these experiments it seems now to be well established that the earthworms are one of the most useful and active agencies in introducing suitable chemical, physical and microbiological changes in the soil and thereby directly increasing the fertility and crop producing power of the soils in which suitable conditions exist for their life activities.

It may, however, be noted that all these observations and researches about this problem of the role of earthworms in soil fertility pertain chiefly to the particular hybrids of earthworms and the topographic, pedologic and climatic conditions which are met with in the soils of foreign countries.

In India, investigation on this problem, however, seems to have been carried out by a few investigators only at one or two centres like Kanpur and Madras. The proceedings of the 'Indian Council of Agricultural Research', New Delhi, three or four years back show that this problem was on the agenda of the Council and that the Council had recommended that investigations on this problem be taken up in a few States where suitable conditions exist especially from the point of utilisation of earthworms on a large scale for increasing the crop-yields. But this question of utilisation of earthworms does not appear to have received the attention it deserves in this country.

With a view to study the effects of the presence of earthworms in soils under the local conditions, we undertook some experiments on the role of earthworms in soil fertility and made a beginning in the elucidation of the changes brought about by earthworms on the soils. Our investigations were no doubt restricted to the local climatic and pedological conditions prevailing in the soils around the Poona city. Yet it is expected that they will apply also equally well to those areas where black soils derived from the basaltic trap rock occur and where climatic conditions, especially rainfall, similar to those at Poona prevail.

The investigation can be conveniently described in three different parts, all being concerned with comparative study of the earthworm casts and the soils which the earthworms inhabit. The earthworms feed on the organic vegetable matter in the soil like plant roots, leaves, etc. and leave their excreta on the surface of the soil which are known as casts. These three parts would be as follows :

(1) A comparative study of the chemical, physical and microbiological properties of 'the earthworm casts' and the corresponding original soils where the above casts are met with.

(2) Study of microbiological properties, such as the nitrifying powers of the earthworm casts and the corresponding soils.

(3) Pot-culture experiments in soils with and without earthworms so that the effect of the changes brought about by the earthworms inhabiting the soils on the crops may be observed and compared with the original soils, i.e. soils without the earthworms.

1. *A comparative study 'of the earthworm casts' and the corresponding original soils*

In August 1948, after the first heavy showers of rains had fallen the earthworms had commenced their activities of boring in the soil-mass. When the casts began to appear on the soil surface they were collected along with the corresponding original soils from five to six different places all situated around the Poona city and these samples were analyzed chemically, physically and microbiologically, the results of which are embodied in Tables I-A, I-B and I-C.

TABLE I-A

Results of chemical analysis of soil and casts collected from five different spots

	Pair I		Pair II		Pair III		Pair IV		Pair V	
	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast
A. Analysis of 1 : 5 Soil :—										
Water extract—										
(i) Electrical conductivity	220	260	180	200	180	290	80	110	130	225
(ii) 'pH' Value	6·40	7·48	7·50	7·58	7·57	7·82	7·76	7·68	7·75	7·68
(iii) CO_3 per cent in gm.	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
(iv) HCO_3 do	0·134	0·168	0·080	0·084	0·084	0·16	0·084	0·080	0·134	0·134
(v)—Cl per cent do	0·012	0·009	0·004	0·009	0·014	0·009	0·004	0·009	0·007	0·009
(vi) Ca per cent do.	0·056	0·070	0·035	0·056	0·047	0·053	0·058	0·056	0·042	0·054
B. *Total carbonate*	3·53	2·72	1·50	1·22	1·63	2·93	1·50	2·18	..	..

TABLE I-A—*contd.*

Results of chemical analysis of soil and casts collected from five different spots.

	Pair I		Pair II		Pair III		Pair IV		Pair V	
	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast
C. Exchangeable bases (in milli-equivalents per 100 gm. sample)										
(i) M.E.V.s of Exchangeable Ca.	32·0	29·0	22·0	22·0	36·0	34·0	33·0	32·0	43·0	49·0
(ii) do. Mg. . .	1·6	2·4	0·4	1·2	8·0	4·4	1·6	2·8	2·2	2·4
(iii) do. Na+K .	1·2	1·4	1·0	1·6	3·0	2·4	2·4	2·8	2·2	2·4
(iv) *Total* Exchangeable basis	34·8	32·8	23·4	24·8	47·0	40·8	37·0	37·6	47·4	53·8
D. Analysis of HCl-extract—										
(i) ($Al_2O_3+Fe_2O_3+P_2O_5$) per cent.	23·8	18·2	13·6	16·4	21·0	20·0	22·0	22·0	24·0	25·20
(ii) CaO per cent . . .	0·616	2·96	3·64	2·01	1·79	1·56	1·62	1·12	1·73	1·72
(iii) MgO per cent . . .	0·64	0·84	1·50	0·80	1·97	1·65	..	..	..	..
(iv) Insoluble sand per cent .	73·70	71·90	79·80	78·72	72·40	71·94	73·10	71·20	64·14	63·66
E. Manurial ingredients—										
(i) Percentage of N . .	0·264	0·282	0·212	0·229	0·106	0·254	0·246	0·327	0·305	0·442
(ii) Percentage of P . .	0·186	0·114	0·048	0·108	0·119	0·201	0·141	0·162	0·162	0·172
(iii) Percentage of K . .	..	..	0·041	0·068	0·058	0·207	0·156	0·152	0·088	0·172

The results of chemical analysis given in Table I-A would show that (1) casts are richer in soluble salt contents as seen from their higher electrical conductivity figures than those of the corresponding soils, (2) the casts are either neutral or alkaline in reaction (' p^H ' value), (3) the casts have higher percentages of exchangeable Na+K and Mg but contain a lower amount of exchangeable Ca than that in corresponding soils.

Chemical analysis of HCl-extract of the samples reveals that the percentages of $Fe_2O_3+Al_2O_3+P_2O_5$ which are generally present in soils in the colloidal state (clay) are higher in earthworm casts than in the corresponding soils. Naturally the percentages of acid-insoluble matter or sand are lower in casts than in the corresponding soils.

The earthworm casts also contain greater amounts of the more important plant nutrients like nitrogen, phosphorous, and potassium.

By excreting such casts containing higher amounts of plant nutrients on the soil surface which is the principal nutritive zone of young plants and crops, the earthworms doubtless cause increase in the fertility of the soil.

Mechanical analysis of the earthworm casts and the corresponding original soils was carried out by the International Method for finding out the percentages of the different sized particles present in them. Table I-B gives the results of analysis of samples from pair No. 4 and 6.

TABLE I-B

Mechanical analysis of soil and cast samples

	Pair No. 4		Pair No. 6	
	Soil	Cast	Soil	Cast
1. Percentage of coarse sand	6·67	1·89	10·05	5·13
2. Percentage of fine sand	41·68	35·35	50·00	49·14
3. Percentage of silt	16·00	18·00	27·00	30·00
4. Percentage of clay	28·00	30·00	7·40	10·00
5. Percentage of moisture	7·65	11·56	4·95	5·13
6. Percentage of loss on ignition	12·50	15·58	20·40	23·20

The results embodied in Table I-B show that the earthworm casts contain greater percentages of finer fractions like silt and clay than that of the same in the corresponding soils. This change in the mechanical composition of the soil is very probably due to the grinding action of the earthworms 'gizzard' wherein the soil eaten along with other food material gets triturated and disintegrated into further fine particles. This process also in a way helps in making the soil more fertile by the breaking down of the complex minerals originally present in it into simpler forms which means that they become probably more easily available constituents especially to the plants growing in soils containing such earthworm casts.

The casts also contain a greater amount of organic matter which no doubt must have been derived from the digestion of organic vegetable matter like rootlets, leaves, and pieces of stems of young plants in the soil by the worms. This is indicated by the greater loss on ignition found in the case of 'casts' than in the soils, because the loss on ignition gives us more or less a rough idea of the organic matter contained in the soil sample.

All the soil and cast samples were examined microbiologically by making the several extracts separately from the respective samples of the earthworm casts and the corresponding soil by adding sterile water and bringing it down to known dilution. Bacterial counts were made after 24, 48, and 72 hours by plating 1 c.c. of the water extracts prepared as above on 'nutrient-agar' plates and incubating the plates at constant temperature viz. 25°C. Table I-C gives the results of bacterial counts.

TABLE I-C

Bacterial numbers in soil and cast samples

	First Pair	Second	Third	Fourth	Fifth	Sixth
Soil .	$59{\cdot}3\times10^{5}$	$24{\cdot}3\times10^{5}$	..	$25{\cdot}0\times10^{5}$	$127{\cdot}0\times10^{5}$	$27{\cdot}5\times10^{5}$
Cast .	$38{\cdot}6\times10^{5}$	$26{\cdot}2\times10^{5}$	..	$44{\cdot}0\times10^{5}$	$117{\cdot}0\times10^{5}$	$26{\cdot}0\times10^{5}$

Thus in three pairs out of the five cases studied, bacterial numbers are greater in soils than those in casts. The lower number in case of casts may perhaps be related to their higher 'p^{H}' value i.e., alkalinity (Table I-A) (only certain types of micro-organisms are possibly able to develop in soils having greater alkalinity while others may fail to do so).

The general conception of higher bacterial numbers as a measure of greater fertility of soils could not, therefore, necessarily hold true in this particular case. Probably the oxydizing process of the decomposing organic matter in the earthworm casts has attained a stage at which the nitrification is to begin while the work of bacteria growing on agar is accomplished and so their period of acting being completed their presence in large numbers on agar could not be observed.

2. *Study of the nitrifying powers of soils and casts*

The process of nitrification of the added organic matter to soil is mainly due to the activities of micro-organisms present in it and the study of this process yields some valuable indication about the fertility status and crop producing power of the soil.

The nitrification was studied by taking 100 gm. of the soil or cast sample and adding to it 30 mgm. of 'N' in the form of powdered oil-free groundnut-cake and 33 per cent of the saturation capacity mositure. The sample was kept in closed wide-mouth bottles and the nitrate-nitrogen formed at the end of every week was determined by the 'phenol-di-sulphonic acid' method. Conductivity values were also determined at the same time. All these results are included in Table II.

From the results of Table II it will be seen that the earthworm casts not only contain higher amounts of nitrate-nitrogen at the start but that they also possess a greater nitrifying power than the corresponding soils. The amount of NO_3-N formed are higher for casts than for soils as can be seen from the results of nitrate-nitrogen content of these samples at the end of first, second, third and fourth week.

The conductivity figures are also higher in every week in case of casts.

Thus the casts excreted by earthworms possessing higher nitrifying power, are expected, when spread on the soil surface, to accelerate the decomposition and

TABLE II

Nitrate-nitrogen formed in four weeks in casts and soil samples

Pair number		In week number				
		Original	First	Second	Third	Fourth
5	Soil.					
	No_3 N (*mgm.*) 100 gm. of soil.	0·2	7·36	12·48	14·80	17·60
	Conductivity of 1 : 5 extract.	105	..	300	310	340
	Cast.					
	No_3 N	0·8	20·80	21·60	25·60	26·40
	Conductivity . .	108	..	400	440	450
6	Soil.					
	No_3-N	..	10·48	14·80	21·20	..
	Conductivity . . .	100	240	300	390	..
	Cast.					
	NO_3-N	..	17·20	21·60	31·60	..
	Conductivity . . .	130	350	410	500	..

nitrification of the organic matter which gets covered up and mixed with the surface soil.

3. *Pot-culture experiments*

The physical activities of earthworms in the soil are summarized as 'burrowing, burying and bruising' in it. Without going into much details of the explanation of all these terms, it can be stated that these activities of the earthworms endow the soil with proper tilth and fertility and establish the proper conditions in the soil leading towards good crop-yields from the soil.

With a view to testing this general conclusion drawn from the laboratory examination of the different samples of earthworm casts and the corresponding soils and to finding out whether it would hold good under Indian conditions also, some 'pot-culture experiments' were carried out with the simple object of observing

how far the presence of earthworms in soils under controlled conditions affect crop-growth. Two crops, first of *jowar* and the other of wheat were taken separately in two successive seasons.

The soil used in these experiments was the black-cotton soil commonly occurring in nearly all the fields round about the Poona city.

The treatments that were tried were as follows, each treatment having six replicates and each pot holding eight plants.

(1) Control i.e. soil only . . . . 6 pots.
(2) Soil + earthworms, 10, per pot . . . . . 6 ,,
(3) Soil + 10, mgm. CuO/100, gm. soil . . . . 6 ,,
(4) Soil + earthworms (10, NO, S) + 10 mgm. CuO/100 gm. soil . . . . 6 ,,

TABLE III-A

Yields of straw (in gm.) of jowar *crop per pot*

Treatment	Average weight in gm. of eight plants from pot numbers						Average of six pots
	(1)	(2)	(3)	(4)	(5)	(6)	
1. Control, i.e. soil only .	46·5	42·0	62·0	49·9	61·0	47·0	51·40
2. Soil + earthworms .	53·5	44·0	58·0	64·0	65·0	73·0	59·50
3. Soil + CuO . . . (10 mgm./100 gm. soil)	84·5	83·0	69·6	62·0	76·5	60·5	72·68
4 Soil + earthworms + CuO (10 mgm./100 gm. soil)	62·0	88·0	136·5	98·0	70·0	64·5	86·50

The effect of the presence of earthworms on the crop-yield was thus found to be beneficial. The per centage increase in yield due to the presence of earthworms in treatment No. 2 and 4 over 1 and 3 respectively (where they were absent) was 15·7 and 19·1. These conclusions were also confirmed by the statistical analysis of the above yield-data.

Seeds of wheat were sown in each pot after the harvesting of the *jowar* crop to see the residual effect of these treatments and naturally the treatments given to each of the pots before sowing *jowar* remained the same. The results of the wheat trial are embodied in Table III-B.

TABLE III-B

Yields of wheat crop (grains) per pot

	Average weight in gm. of eight plants per pot numbers						Average yield per pot
	(1)	(2)	(3)	(4)	(5)	(6)	
1. Control, i.e. soil only .	1·0	1·0	3·0	2·0	1·0	2·0	1·75
2. Soil + earthworms .	4·6	4·0	3·0	3·0	3·5	3·0	3·52
3. Soil + CuO . . . (10 mgm./100 gm. soil)	1·0	1·9	1·7	1·3	1·6	1·5	1·50
4. Soil + earthworms + CuO (10 smgm./100 gm. oil)	2·1	1·7	2·1	2·7	2·4	2·0	2·17

Thus in the case of wheat trial also, there was an increase of 101 per cent and 24 per cent respectively in the yields of wheat crop (grains) due to the activities of earthworms introduced into the soils in pots from treatments No. 2 and 4 as compared to treatments No. 1 and 3 wherein earthworms were absent.

All the above analysis and experiments conclusively prove the beneficial effects of earthworms on 'soil conditions and plant growth'.

The practical aspect of the problem is to cultivate earthworm cultures artificially by means of suitable methods and to collect earthworm capsules and to allow the earthworms to develop under artificial and controlled conditions. Such capsules or the developed earthworms could then be distributed to farmers for spreading them over their fields and farms after the ploughing of fields and farms and before the sowing of seeds in them. Such technique is very rapidly being developed in foreign countries and it would also be in the fitness of things that agriculturists in this country also adopt such a method of farming also termed as 'earthworm-tillage' in order to obtain increased crop-yields from the Indian soils already known to be depleted of fertility.

REVIEWS

SERVICING AND MAINTAINING FARM TRACTORS

By J. Johnson and Alvin H. Hollinberg

Published by McGraw-Hill International Corporation, Book Export Division, 330 West 42nd Street, New York 18, N. Y., 1950, pp. XVI+313, Price $3·00)

ONE of the main draw-back of popularity of mechanised agriculture and the reason, why an average farmer in India today hesitates to purchase a tractor is the lack of technical skill required for maintenance and operation of the tractors. The machine is considered to be very complicated and requiring skilled and expert hands even for its running and normal maintenance, and as such whenever tractor goes out of order, instead of rectifying the defect, invariably they start looking for 'expert' to put it back again in order. As a matter of fact, such 'expert' are even considered necessary for its normal routine check-up and rendering lubrication change-overs and service. Tractors are often lying idle on a such occasion and also when only minor servicing is required.

Handling the tractor by in-experienced persons and a wrong approach to the machine has also lead to many a serious trouble and rendered much damage. The result is that not only it takes a lot of money, but renders the tractor out of use for the farmer, when probably it was most needed.

Many accidents take place with tractor through improper handling and careless driving resulting in damage to lives and property. Quite often the ignorance may be the cause of such an accident. If the tractor owner and driver simply know the precautions to be observed, many farm accident can be averted. In the absence of any such guidance the farmers very often learn by practice only—a very costly experience indeed.

This book is written in a very simple and lucid way. It deals with the practical side only of the precautions, servicing and maintaining the farm tractors. Though no effort has been made to make the reader expert in handling all the tractor repair job, it gives very clearly the procedure to be followed for tackling the ordinary maintenence and servicing jobs required to be undertaken during operation of tractors on a field with a clear understanding of his action. No guess work is given in the book and accompanying diagram makes the text very understandable. More advanced jobs of repair and overhauls are left for the experts. Written by practical agricultural men, it justifies its title very well and should be on the shelf of every tractor owner, particularly those who are far off from the available technical labour. 'Storage and Safety First' practices are treated in a very good and illustrative manner and should be known to every farmer, as it will go a long way to avoid accidents etc., and make the tractor a popular

machine, instead of 'dreadful'. Summaries are given at the end of each chapter which present the contents of chapter in a nut shell.

All along the context, the 'theory' is avoided which makes the book more interesting to practical man. It is however felt that more details should have been included for fuel grade and selection and working principles and constructional details of internal combustion engines. An elementary chapter on comparison of tracked and wheeled tractors and some more details on maintenance and servicing of tracked tractors should also have been included.

The book is very useful and will serve its purpose well as indicated by its title.

(J. S. M.)

DIRECTORY OF INTERNATIONAL SCIENTIFIC ORGANIZATIONS

(*Published by United Nations Educational, Scientific and Cultural Organization, Paris, $ 1·00 pp. 224, 1950.*)

THIS publication has been brought out by the UNESCO as it is considered that the active co-operation of competent non-governmental organizations is essential for achieving the objectives of the UNESCO. The organizations have been grouped in three main divisions—(1) Basic Sciences, (2) Applied Sciences with sub-divisions of Agricultural Sciences, Engineering Sciences and Medical Sciences, and (3) Miscellaneous. International Scientific Organizations in each field as also regional organizations have been catalogued and information given regarding the address, aims, constitution of the governing body, short history, etc. of each association. It is interesting to note that in the chapter on Basic Sciences, the activities of 56 associations have been described, in the chapter on Agriculture those of 36, in the chapter on Engineering those of 24, in the chapter on Medicine those of 58 and in the chapter dealing with miscellaneous association those of 28. This will be a very useful book of reference in a library of a scientific department and technical institute. (J. C. G.)

FORAGE AND PASTURE CROPS

By W. A. Wheeler

(*Published by the D. Van Nostrand Company, Inc., New Yark and Macmillan Co. London, pp. XI-752, 1950*)

WITHIN recent years several books on forage and pasture plants have appeared and many of them are from the United States of America. The appearance of these publications are an indication of the importance these crops have assumed in

the national economy of Western nations. In many of these countries forage production is geared to the livestock Industry, and these two functions as complements of each other. Thus the development in either one helps the progress in the other. In the United States of America there are vast resources of forage and pasture production and their conservation and proper use is of national importance. Wheller's book serves to bring out these facts and points out the ways and means by which to use the resources to the best advantage.

The book is divided into four parts. The first part is devoted to a general consideration of the following aspects ; the importance of grasses and legumes as forage and pasture crops, the soil and manurial requirements of these crops, the importance of innoculation of legumes, a lack of knowledge of which accounts for so much failure in legume introduction from one country to another, establishment and management of pastures, silage and hay making, improvement of forage and pasture herbage and pests and disease affecting these crops. Each crop is dealt with thoroughly but concisely and valuable information on each and every aspect of forage production, beginning from the time of sowing to the time of harvesting and storage, is given.

Parts II and III deal with the important and well known legumes and grasses respectively. Among the legumes alfalfa, clovers, veteches, peas, etc., and among grasses timothy, fescues, orchard, blue, brome, wheat, buffalo grasses and some non-grasses are dealt with in adequate detail. The part IV includes a table of information on legume and grass seeds and selected references on forage crops classified according to states in the United States of America. The latter covers 32 pages of double column of close type, and lists nearly 1,000 references. Besides these 300 references of the U. S. Department of Agriculture and over 60 miscellaneous references are included as bibliography.

In the preparation of the book Mr Wheeler has been ably assisted by a team of workers of the U. S. Department of Agriculture, the State Experimental Stations, and University Professors of agronomy and others. But the credit must necessarily go to Mr Wheeler for marshalling all the available facts and data gathered from the numerous reports and publications of all the States, and presenting them in a readable form. At the back of Mr Wheeler's efforts lies thirty years of experience gained from thorough study of the forage and pasture crops of the United States. The work done is prodigeous and the result is worth far more than the effort expended. It is encyclopaedic in information and gives individually and severally information on all aspects of production of the more important forage and pasture legumes and grasses.

While the book is primarily useful to those in the United States, it is nevertheless of considerable importance to others outside the States, in showing them what is required to be undertaken to develop the forage and pasture resources of a country. To those who are grass minded in this country the book will be of inestimable value and will help them in planning to organize the work of development of the million of acres of misused and impoverished grasslands. When the importance of grasslands is realized then there is hope for the improvement of livestock in the country. (L. S. S. K.)

OFFICIAL METHODS OF ANALYSIS

(Published by the Association of Official Agricultural Chemists, Washington 4 D. C. 7th edition, 1950, pp. 910, 73 illustrations. Price $10·00)

THIS valuable work has attained world wide reputation among analytical chemists in general and agricultural chemists in particular. Its methods are recognized as an authority by courts in the United States of America. Agricultural chemists all over the world and in India, consider the book as an indispensible addition to their libraries and as a reliable guide in their day to day analytical work.

Founded in 1884 by the late Dr H. W. Wiley, Chemist of the Department of Agriculture, the Association of Official Agricultural Chemists has been continuously devoting its time and attention to the study, development and recommendation of analytical methods applicable to materials necessary for agricultural production and to the analysis and evaluation of the products of agriculture. The membership of the association was originally restricted to agricultural chemists holding official positions in the U. S. A. With the passing of years and with experience gained, the membership was gradually extended to those scientific men engaged in the control of foods and drugs.

Starting as a modest compilation of tested and recommended methods, it had passed through six editions by 1951 and has become a great treatise covering the whole field of agricultural and allied analysis. The one under review is the seventh edition occupying a thousand pages of closely printed matter under the editorship of Dr H. A. Lepper, assisted by a committee of six, who in turn are assisted by a number of referees from several institutions throughout the U. S. A. The present edition gives all the new methods and changes adopted by the Association between the years 1945 to 1949. The older classification of 'tentative' and 'official' has been dropped now, and the methods are classified according to new designations official first action and procedure.

About 100 pages are devoted to soils, fertilizers agricultural materials and plants. The next hundred pages are devoted to the analysis of baking powders and beverages. Another five hundred pages deal with the analysis of beans and bean products, cereal foods, dairy and poultry products, fruits and fruit products, grain and stock feeds, and meat and meat products. These are followed by methods devoted to special subjects such as microbiological and microchemical methods, radioactivity, and methods for the estimation of vitamins. The important subject of standard solutions finds a place. Attention has been paid to clear instructions. The whole publication is a well indexed encyclopaedia covering a wide field. No agricultural chemists' laboratory can afford to be without this book.

In India there is need for agreed uniform methods of analysis. About 40 years ago the late Dr J. W. Leather, who was Imperial Agricultural Chemist at Pusa recognized

the need for such methods. In consulation with his colleagues he issued a small publication entitled '*Official and Recommended Methods of Analysis*'. For a time this was adopted by the Agricultural chemists' laboratories in India. As Agricultural Departments expanded these methods were somehow dropped and a variety of methods were employed. It was found very difficult to compare data from different laboratories, particularly when considering the soil plant relationships. Later, between the years 1940 and 1944 the reviewer and his colleagues at Indian Agricultural Research Institute carried out analysis of a number of soils from India. These samples were collected at an identical period by persons familiar with soil sampling and analyzed by chemists with at least 20 years of experience in soil analysis. This work was initiated with a view to forming the basis for the evolution of agreed methods of analysis. Subsequently Indian Council of Agricultural Reaserch appointed a Committee for similar purpose. This renewal of effort, it is hoped, will have continuity. Until such time as agreed methods are evolved for India it will be desirable to adopt methods of the Association of Official Agricultural Chemists. (B. V. M.).

THE CHEMISTY AND ACTION OF INSECTICIDES

By H. Shepard

(*Published by McGraw Hill Book Company, New York, 1951, pp. 504, Price $7·00*)

INSECTICIDES play a very important role in applied Entomology since the most common method of insect control is by the application of substances which are poisonous to various pests. The examples of injurious insects which can be completely controlled by biological, cultural or other similar methods, are still comparatively few. There are some who decry the use of chemicals on the ground that they involve interference with the balance of nature and that by employing them we are in danger of creating new problems. This argument, however, falls to the ground when we consider that all progress in agriculture is essentially interference with the balance of nature as nature alone could never have led to the growth of high yielding varieties of wheat, corn, cotton, sugarcane or rubber over large areas.

Annual losses in the United States caused by insects are estimated to be as much as $4,000,000,000. Therefore, investment in insecticides is now considered a form of crop insurance as the purchase of fertilizers. In tropical and sub-tropical countries the losses are heaviest as the climatic countries are more conducive for the rapid multiplication of pests and comparatively cultivators are yet unfamiliar with the latest developments in pest control. The production and consumption of insecticides is the highest in the U. S. A. at present and there have been phenomenal progress in the development of new insecticides during the last decade in that country.

Shepard has rendered a valuable service to applied chemistry by giving an exhaustive account of the chemical constitution or chemistry of various pest control products in his book under review. This will undoubtedly prove a useful work of reference to entomologists engaged not only on research in insecticides but on

their applications in the field as well. Some space is also devoted to common fungicides chiefly seed dressings containing sulphur, copper or mercury. The account given of the 'action of insecticides' is not so exhaustive as that of 'chemistry of insecticides'. The author cannot be blamed for this because our knowledge of ecology and physiology of insects is yet meagre and admittedly more fundamental scientific work on the physiological processes of injurious insects is needed to enable the applied entomologist to use insecticides most economically and effectively.

During the last two years, some very potent insecticides such as aldrin and dieal-drin have been developed in the U. S. A. They are not described in the book obviously because perhaps the manuscript had been completed much earlier than the date of its publication or author's preface. The get up and printing of the book is good. (H. S. P.)

DESTRUCTIVE AND USEFUL INSECTS—THEIR HABITS AND CONTROL

By C. L. Metcalf and W. P. Flint

(*Published by R. L. Metcalf, Third Edition, McGraw-Hill Book Company, New York, Toronto, London 1951, 1-XIV, pp. 1071, 584 illustrations*)

THE Destructive and Useful Insects by Metcalf and Flint originally published over 20 years ago is now well known to all economic entomologists in different parts of the world. In view of the importance of insects as the most destructions agency in regard to agricultural and the fact that insects are responsible for the spread of numerous serious diseases of man and his domestic animals, the study of insects has made very rapid progress in the past 10 or 15 years. The chapters dealing with Insect Physiology, Nutrition, etc., have been almost entirely rewritten. Mr R. L. Metcalf has really done good service to his old colleagues and the entomological world in revising the book thoroughly and bringing it up-to-date. Mr C. L. Metcalf was eminently suitable for this work as he was associated in the publication of the earlier editions by the original authors.

The first ten chapters of the book are devoted to the Anatomy, Physiology and Morphology of insects and other fundamental aspects of Insect Control. Then a chapter is devoted to the pests of each of the important groups of commodities such as corn, legumes, cotton, tobacco, fruits, etc., followed by two chapters to insects which are injurious to domestic animals, man, etc. The account of various pests occupies the bulk of the book, viz. 600 pages. Though the pests described are of particular interest to the U.S.A. but since some of the pests in the other parts of the world are allied to them, this book will be found useful by workers in other countries also besides the U.S.A. and Canada. However, the first 400 pages dealing with general entomology are of wide interest to all entomologists working in different countries and therefore the book continues to be one of the standard text book of economic entomology for use by students, research workers, teachers in the entire English speaking part of the world. Similarly new chapters dealing with aerosols, aircraft dispersal of insecticides have been added to the previous edition.

The book is fairly well illustrated, its get up and printing are excellent. (H.S.P.)

AN EXPERIMENT IN FORESTRY

By N. D. G. James

(*Published by Basil Blackwell, Oxford, 1951, pp. 102*)

THIS little book of some 100 pages contains a descriptive account of a number of small experimental plantations of exotic and indigenous species, both hard-, wood and coniferous, made in a forest garden attached to the Royal Agricultural College Cirencester, England. The garden was started in 1903 on a site provided by Lord Bathurst. The land had been rough pasture from time immemorial, but had been under the plough for ten years before the garden was formed. A fairly detailed description is given of the species planted in each sub-plot, the treatment accorded and the present condition of the crop, together with data relating to age, height, diameter and volume. Particulars of the ground flora and of insect and fungal attacks on the trees are also given.

The two World Wars interrupted the continuity of scientific management of the garden as the Agricultural College was closed during the war years. There are also gaps in the record maintained of the details of treatment accorded to the various plantations.

As in the case of the plantations at Alice Holt (which is the centre of forestry research in Great Britain and at Bagley Woods, which are the training ground of students in the Oxford School of Forestry, Sir William Schlich (who was Inspector General of Forests to the Government of India during the period 1881-85) was closely connected with the initiation of the forest garden at Cirencester.

The total area of the garden is just under 11 acres of which the area occupied by numbered plots is only 5 acres ; there being ten plots ; each plot is approximately half an acre in extent. In every case the plot is divided into two or more, in one case as many as six, sub-plots. Since marginal effects are likely to be pronounced in such tiny plots, the results of the plantation work should be regarded as of general silvicultural interest rather than of strictly scientific or statistical value. Conclusions of a guarded nature have been drawn by the author, Mr N. D. G. James, who was in charge of the garden as Lecturer in Forestry at the Royal Agricultural College, Cirencester, from 1947 to 1950, and is now Fellow and Bursar of Corpus Christ College, Oxford. In the circumstances the title of the book '*Experiment in Forestry*', appears to be rather an ambitious one.

There are a few minor errors of which the omission of *Acer pseudo-platanus* (sycamore) from the list of species growing in the garden is perhaps the most important.

The book is an interesting guide to one of the oldest forest gardens in England. and is likely to be useful to students. Its usefulness could perhaps be increased in future editions by the inclusion of available data regarding the age of first flowering and fruiting, and the fertility of the seed of the various species experimented with. (C. R. R.).

SCIENTIFIC HORTICULTURE

(*Published by the Horticultural Education Association and Printed by Gibbes and Sons Canterbury, Kent, Vol., X, 1950-51 pp. 240, Price 10s. 6d.*)

THE journal contains articles on the horticultural industry of the Netherlands New Zealand and other European countries from eminent scientists and high officers employed in the industry. The present volume contains as many as 23 papers covering wide range of subjects such as ' Meteorology and Horticulture ', ' Pot Plan, Growing at Ballieston ', ' A survey of flower production in South-West England etc., etc.' The journal is really useful for those interested in horticulture in the temperate zone countries.

The general get-up and printing of the journal is good. It is profusely illustrated with high quality photographs and diagrams which make the text easily understandable. Another notable feature is the list of recent books on Horticulture and its allied sciences given at the end of the journal. This list is quite exhaustive and should prove very useful for the Horticultural Research workers. The journal will surely increase the knowledge of Horticulturists on a variety of subjects which are rarely to be found in a single issue. (B. S. B.)

READINGS IN AGRICULTURAL ECONOMICS—REHABILITATION OF LOW-INCOME GROUPS IN AGRICULTURE

(*Published by the Indian Society of Agricultural Economics, Bombay 1951, Price Rs. 9, pp. 288*)

THE problems of ' low income ' and ' sub-marginal ' groups among agriculturists are not only confined to under-developed and undeveloped areas, but also exist in varying degrees in the more advanced countries. The success or failure of the measures taken in one part of the world to improve the social and economic position of the agricultural population can be a useful guide in chalking out appropriate measures in other areas. The main objective of the Indian Society of Agricultural Ecomomics in devoting the second volume in their series ' *Readings in Agricultural Economics* ' to ' *Rehabilitation of low-income groups in Agriculture* ' is to focus attention on this vital problem and to point out the intensity and the scale of efforts necessary for its solution. The readings consist of 25 experts, which give useful information regarding the measures adopted in other countries. (S.R.S.)

RELIEF MEASURES IN FAVOUR OF LOW INCOME FARMERS IN EUROPE

EDITED BY OLAF E. LARSON

(*Published by the Indian Society of Agricultural Economics, Bombay 1951, Price Rs. 2/8, pp. 150*)

THE problem of rehabilitation of agriculture has to be approached from various angles in order to achieve speedy and permanent results. The complex nature of the task is borne out by the five sections into which the study is divided, viz., (i)

Principles of Economic Development, (ii) Rehabilitation of Backward Areas, (iii) Problems of Farm Indebtedness and Inflated land Values, (iv) Agrarian Reforms and (v) Rehabilitation of the Individual. It is recognized that progress in agriculture is often conditioned by changes in the other sectors of the economy and improvement of the human element in production. Even in the agricultural sphere, piecemeal measures like relief and control of indebtedness will prove mere palliatives unless these are accompanied by positive steps to improve agricultural efficiency through a broad-based policy of rehabilitation.

The necessity of introducing agrarian reforms to rectify mal-adjustments between resources and population has been felt in most of the countries both in the Eastern and Western hemispheres. It is interesting that the experience in some of the foreign countries has demonstrated the need for a certain element of compulsion and State initiative for promoting the process of consolidation of holdings. Although schemes for compulsory re-distribution of all large holdings, attempted in some foreign countries may not be immediately practicable in India due to numerous social, administrative and financial difficulties involved, the measures adopted by some of the States to fix maximum and minimum limits on future transfers, to provide facilities to the protected tenants to purchase lands cultivated by them and to eliminated intermediaries will help in achieving a better re-distribution of land in the country. As regards what constitutes the fair lease, it is stressed that the landlord and the tenant should share the income in the same proportion as they contribute to the expense of the operation of the farm.

On the subject of control of land values, the compiler of the volume has presented the conflicting views of Dr Contanzo and Dr Hammer and the 'middle-course' suggested by the Australian Commission on Rural Reconstruction which favours only temporary pegging of land prices in special circumstances.

The Commission further favours the setting up of a national organization for disseminating information in regard to productive values of land as a measure to check speculation and over-estimation of the values in the open market. (S. R. S.).

TEN YEARS OF RURAL REHABILITATION IN THE UNITED STATES

EDITED BY SIVMUND V. FRANENDORFER

(*Published by the Indian Society of Agricultural Economics, Bombay 1951, Price Rs. 5, pp. 150.*)

THE Society has supplemented its main publication by two other publications entitled *Relief Measures in Favour of low-income Farmers in Europe* and *Ten Years of Rural Rehabilitation in the United States* which give somewhat detailed information regarding measures adopted in some of the countries of Europe and the U. S. A. The remedy proposed by Dr Sivmund V. Franendorfer for the rehabilitation of low income group in Europe, viz., Co-operation in its true conservative sense

of combining individual forces, without prejudicing individual property and individual freedom, and second, equally important, rural education, also promises great results for this country. The support given to the idea of multi-purpose society by the sponsoring spokesman of the last-mentioned volume is broadly in line with the present trend of thought in our country.

The development of agriculture is of vital importance to India. There has not only been a spate of legislation on agrarian reforms in the States in recent years but a comprehensive plan to solve social and economic problems on a coordinated basis is also being drawn up by the Planning Commission, which, when implemented, will yield results of far-reaching importance. An increasing emphasis is being laid on the re-organization of rural development machinery and establishment of land army, for the purpose of achieving land transformation. This publication would be valuable not only because it shows some similarities between conditions and policies in India and other countries, but also because the contrasts depicted by it may prove to be quite thought-provoking. (S. R. S.)

FARMER AND STOCK-BREEDER YEAR BOOK—1951

(Published by Farmer and Stock-Breeder Publications Ltd., London, SEI Price 7s. 6d. net pp. 376, over 163 illustrations.)

A NEW edition of the Farmer and Stock-Breeder Year Book—1951 has just been published. This is the 75th year of this publication. The book contains nearly 400 pages of useful information for stock-breeders and those interested in purchasing equipment for livestock farming.

One section of this book consists of a series of papers on food problems, marketing boards, buildings for pigs, the destruction of weeds by hormones, improved feeding of calves, the handling of liquid manure, beet harvesting machinery, and the year's progress in agricultural equipment. These articles are written by men of many years of experience and considerable knowledge in the respective fields. Each article is well illustrated to make it more informative than it might otherwise be.

Another section consists of numerous very fine illustrations of the different prize winners in British livestock shows during the past year. Every kind of farm animal, except poultry, is represented. The extremely good quality of the best show stock of Britain can be appreciated fully by studying this section of the book. Included also are advertisements of a very large number of breeders who have stock for sale and suppliers of seed potatoes, nursery stock and equipment.

A brief section on poultry, including an article on selecting the system of rearing poultry, by an expert in this field, is included. The paper is followed by a large number of advertisements of breeders of poultry and auctioneers of all types of farm animals.

The final section of the book includes addresses and personnel of official bodies, farm organizations, research and educational institutions, the dates and places of principal shows; artificial insemination centers; British and foreign diplomatic

officials concerned with agricultural and livestock development in Britain and those of Britain who are stationed abroad ; legal, tax and insurance data ; rations for stock ; weather forecasts ; statistics and prices ; wages ; British farming records; pedigree sales ; tractor specifications ; and a buyers' guide.

One very interesting feature of the book this year is the three pages given to British farming records. This includes the highest price at auction for cattle, sheep, horses and pigs ; dairy cattle production records ; and miscellaneous records. Whereas Carnation Madcap Ormsby Fayne, an American Friesian cow, held the world's record of milk production in 365 days, viz., 41,943 lb., a few years ago, having taken that record from an English Shorthorn cow, this book reports that the record is now held by a British Friesian cow, Bridge Birch. The record, it is reported, is 45,081 lb., established in 1947. There are a number of other interesting records reported ; for example, a British Friesian cow, Craigbet Rosan, set a record of 1,630 lb. of butterfat in 365 days in 1947, a Jersey cow, Lady Spotted Pearl, produced 4·2 lb. of butterfat in 24 hours in 1930 ; and a British Friesian cow, Garsdon Minnie, produced 198 lb. of milk in 24 hours in 1948. Other interesting records include ; a calf of 158 lb. at birth ; 5 calves at one birth ; a lamb of 25 lb. at birth, 6 live lambs at one birth ; one litter of 26 pigs of which two died ; 14 hog pigs in one litter ; one donkey that lived to 65 years of age ; a Shorthorn bull which sold for 14,500 guineas ; 223,917 lb. of milk produced in 15 lactations by a Dairy Shorthorn cow, Winton Gentle 2nd ; and a Lincoln sheep that sold for 1,680 pounds sterling. Many other fascinating records are included.

The book is well printed and well bound. A fine quality of paper is used throughout. The photographs are of excellent quality and many of the advertisements include coloured illustrations. Those who are concerned with any phase of the livestock industry will find this book of considerable value and interest. (J. N. W.)

REGIONAL SURVEY OF ECONOMIC RESOURCES OF INDIA, KOLHAPUR.

By Dr P. C. Patil

(*Published by the author under the authority of Government of Bombay for the Bureau of Economics and Statistics, 1950, pp. XXV + 425, price Rs. 24-14.*)

This is a comprehensive regional survey of Kolhapur State. The book is divided into three parts ; Part I gives an account of the physical features of the State, its administration, geology, valleys and rivers, climate, irrigation, land use, food problem, communications and allied matters. Part II deals with agriculture, cooperation, rural credit and indebtedness, education, forests, industries, famines, ravages of locusts, etc. Part III contains a directory of statistics regarding population, social institutions, utility services as well as glossaries of technical terms, botanical names. A good deal of effort has gone into the preparation of this work. Copious data have been given regarding the resources of the region and some useful suggestions have also been offered by the author regarding the lines for further development. While the survey of resources is quite useful, the treatment of some of the current economic problems, e.g., standard of living, food problems is not such as to satisfy any serious student of economics. (M. S.)

MGIPC—M—2 AR—13-1-53—780.

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Indian Journal of Agricultural Science, Vol. XXI, Part II, June, 1951.

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Indian Journal of Agricultural Science, Vol. XXI, Part III, September, 1951.

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The Editorial Board, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Indian Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

INSTRUCTIONS TO AUTHORS

Articles intended for *The Indian Journal of Agricultural Science* should be accompanied by short popular abstracts of about 300 words each.

In the case of Botanical and Zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the articles, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets when the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state 'original not seen'. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized, the size adopted being crown quarto (about $7\frac{1}{4}$ in.$\times 9\frac{5}{8}$ in. cut), no text-figure, when printed should exceed $4\frac{1}{2}$ in. $\times 5$ in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{1}{4}$ in.$\times 8$ in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.